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MAY, 1918



Bulletin of the American Institute of Mining Engineers

PUBLISHED MONTHLY

SPECIAL FEATURES

TECHNICAL PAPERS, See page i.

COLORADO MEETING

WESTERN TRIP OF INSTITUTE OFFICERS

PRESIDENT'S ADDRESS

**CALIFORNIA MANGANESE AND QUICKSILVER
(SAN FRANCISCO SECTION)**

EMPLOYEES' WELFARE

**INDUSTRIAL REORGANIZATION AFTER THE
WAR (MONTANA SECTION)**

**CONCLUDING DISCUSSION AT NEW YORK
MEETING,**

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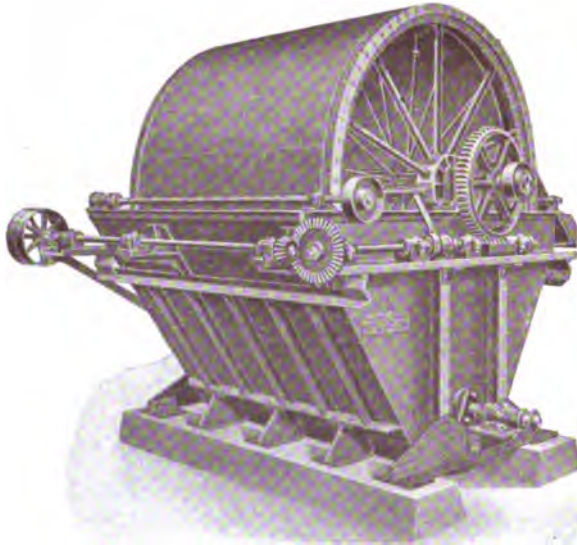
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Pamphlet 28-C describes it fully and contains matter well worth reading

Colorado Iron Works Co.

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NEW YORK, N. Y.

Denver, Colo.

Bulletin of the American Institute of Mining Engineers

No. 137

MAY

1918

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*Reading and Writing Rooms at Headquarters, for the use of Members
of the Institute and their friends*

FACILITIES FOR MEMBERS AT INSTITUTE HEADQUARTERS

The Institute maintains for the use of members (and especially for the use of out-of-town members) a reading and writing room, where all usual office facilities are available, including telephone, telegraph, receipt, forwarding and care of mail and express packages, etc. A file of current magazines is also maintained in this room, and the Institute's staff will lend its best efforts to serving the members in connection therewith. The Institute also maintains for the use of its members free dressing rooms, library research department, etc. Attention is called to these facilities at the present time in the belief that they may be especially useful to out-of-town members in connection with the Meeting.

DRESSING ROOMS

On the ground floor of the Engineering Societies Building are a number of free dressing rooms, where members will find the necessary facilities. This is particularly intended for members who arrive in New York on early trains, or who desire to make a change of clothes for evening entertainments. The building is open from 8 a.m. to 10 p.m., and access may be had at other hours by ringing the doorbell.

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COLORADO MEETING, SEPTEMBER 2 to 7, 1918

A tentative plan for the Colorado Meeting has been formulated as follows:

One day will be spent at Denver, one day at Colorado Springs, one day at Cripple Creek, a trip by automobile to the top of Pike's Peak, one day at Pueblo, one day at Leadville. All the principal mines and mills of the districts mentioned will be visited, including the gold mines in Cripple Creek, the lead, zinc, and steel works of Pueblo, the production of ferro-molybdenum by electric furnace at Leadville, etc.

Special arrangements are being made for the social entertainment of ladies at all points; one evening at Colorado Springs will be devoted to a reception and dance, and the usual dinner will be given on another evening.

The following papers have already been accepted for the Colorado Meeting, and some have already been published:

Fireproofing Mine Shafts by the Anaconda Copper Mining Co. By E. M. Norris. (March Bulletin.)

Air Blasts in the Kolar Gold Field, India. By E. S. Moore. (March Bulletin.)

The Use of Coal in Pulverized Form. By H. R. Collins. (April Bulletin.)

Coal Mining in Washington. By F. A. Hill. (April Bulletin.)

Carbocoal. By C. T. Malcolmson. (May Bulletin.)

Gaging and Storage of Oil in the Mid-continent Field. By O. U. Bradley. (March Bulletin.)

An Interpretation of the So-called Paraffin Dirt of the Gulf Coast Oil Fields. By A. D. Brokaw. (April Bulletin.)

The Theory of Volcanic Origin of Salt Domes. By E. DeGolyer. (May Bulletin.)

- Example of the Use of Well Logs. By Mowry Bates. (May Bulletin.)
 Oil in Southern Tamaulipas. By Ezequiel Ordoñez. (May Bulletin.)
 The Geology of the Oil Fields of North Central Texas. By Dorsey Hager. (June Bulletin.)
 The Limonite Deposits of Mayaguez Mesa, Porto Rico. By Charles R. Fettke and Bela Hubbard. (March Bulletin.)
 Hand-sorting of Mill Feed. By R. S. Handy. (April Bulletin.)
 Oxygen and Sulphur in the Melting of Copper Cathodes. By S. Skowronski. (March Bulletin.)
 Relation of Sulphur to the Overpoling of Copper. By S. Skowronski. (March Bulletin.)
 Electrolytic Zinc. By C. A. Hansen. (March Bulletin.)
 Practice of Antimony Smelting in China. By C. Y. Wang. (April Bulletin.)
 Man Power. By J. Parke Channing. (May Bulletin.)

Other papers now in preparation for the Colorado Meeting are devoted to the following subjects:

- Vacuum Precipitation on Zinc.
 Comparative Grinding Tests on the Ores from One-quarter of the Largest Mines of America.
 Roasting Cripple Creek Ores for Cyanidation.
 Geology of Cresson Mine, Cripple Creek.
 Chlorination of Gold Ores.
 Bromination of Gold Ores.
 Extraction of Potash from the Waters in Lakes in Nebraska.
 Use of Spiegeleisen in Steel Manufacture.
 Coal and Coal Mining.
 Oil Shales of Colorado.
 Radium.
 Molybdenum.
 Manufacture of Ferro-alloys in the Electric Furnace in Colorado.
 Excavating Machinery at the Ajo Plant.

The Committee on Papers and Publications has set June 1, 1918, as the closing date for the receipt of manuscripts intended for the Colorado Meeting. Manuscripts must be received by the Secretary on or before this date. If they are sent through members of the technical committees they must be sent to those committees long enough in advance to be forwarded and in the hands of the Secretary by the time specified.

MEETING OF THE BOARD OF DIRECTORS, MARCH 22, 1918

Thirteen Directors, the Secretary, and seven guests were present. The formation of a Philadelphia Section was discussed.

The proposed rules for admission of additional societies to membership in Engineering Council were approved.

An invitation was extended to the American Institute of Metals to become affiliated with the Institute upon the general terms proposed in the report of the Joint Conference Committee of the American Institute of Metals and the American Institute of Mining Engineers.

The request of the Iron and Steel Committee to hold a meeting in Milwaukee during the week of Oct. 7, 1918, was granted.

The reports of the Treasurer and Finance Committee were accepted.

A change in the By-laws was proposed.

Thirty Members, two Associates, and four Junior Members were elected. The status of two Junior Members was changed to Member. The resignations of seven members were accepted. The dues of two members who are on active duty at the front were remitted. One member was reinstated to membership.

The name of the Committee on Adoption of the Metric System was changed to Conference Committee on Proposed Adoption of the Metric System.

Exchange of Membership Room and Library privileges with the Engineering Association of Nashville, Tenn., was authorized.

The following sums were appropriated for the year 1918: \$125 to the Montana Section; \$50 to the Tulsa Section; \$100 to the Boston Section.

The Finance Committee was authorized, at its discretion, to purchase Liberty Bonds for repurchase by office employees of the Institute.

The President was empowered to appoint a Committee on Iron and Steel and a Committee on Non-ferrous Metals to advise with the U. S. Tariff Commission.

BRADLEY STOUGHTON, *Secretary*.

WESTERN TRIP OF INSTITUTE OFFICERS

Officers of the Institute have been entertained by members at nine meetings in different parts of the country during the months of March and April. Institute policies have been discussed by the officers and by members present at the different meetings, with the result of bringing about a better understanding of Institute policy among the members; it has also been made clear how various suggestions are viewed by members who are not all in close touch with Institute activities and with the policy of the Board of Directors.

President Jennings devoted his remarks chiefly to an account of Institute activities in connection with Government service for the war, and presented an able address on the relations of labor and capital, with special relation to possible changes that may be necessary during the reconstruction period following the war. This carries forward the suggestion made by him in taking up the reins of government at the Annual Dinner on February 20, 1918, and makes available a paper which has aroused great interest at the different meetings; this address will be found on a following page.

In referring to Institute activities in connection with the war, the President mentioned especially the Naval Consulting Board, the War Committee of Technical Societies, the War Minerals Committee, and the census of engineers, prepared not only by the Institute in connection with the Bureau of Mines, but also by the American Society of Civil Engineers, the American Society of Mechanical Engineers and the American Institute of Electrical Engineers. He announced also the appointment of two committees, one on ferrous and one on non-ferrous metals, advisory to the Tariff Commission, and the appointment of a member of the Committee on the Excess Profit Tax, having especially to do with the question of excess profit taxes on gold mines. He also announced the appointment of a new committee known as the Committee on Industrial Organization, which will devote its energies largely to the question of relations of capital and labor and of "human engineering."

First Vice-president Charles W. Goodale continued the subject of the relations of capital and labor, introduced by the President, and also discussed in more detail the work of the Committee on Industrial Organization, which he described as an outgrowth of the previous committee known as the Committee on Safety and Sanitation. The President

has appointed First Vice-president Goodale as Chairman of a sub-committee on Social Surveys.

Secretary Stoughton devoted his address chiefly to a discussion of suggestions that had been made for innovations on Institute policy, and sought expressions of opinion from the members as to these various suggestions.

In this connection, he referred especially to a proposal for a change in the name of the Institute to the American Institute of Mining and Metallurgy. He outlined the arguments that had been presented in favor and opposition to this change, which, he said, was first made in 1912 and then abandoned without ever being brought to a vote, because of other matters deemed to be more important at that time, which were before the membership for decision. Slightly more than 50 per cent. of the Institute members are mining engineers, and somewhat more than one-third are metallurgists, who are not qualified as mining engineers. A large number of these metallurgists have never even seen a mine, and therefore are reluctant to appear, by implication, as mining engineers through membership in the American Institute of Mining Engineers. It has also been ascertained that there are many hundreds of metallurgists who decline to join the Institute because of the name. In a recent campaign for new members in a large industrial center, the chairman of the committee found that a great many well qualified and able metallurgists declined to join the Institute on this ground. The Secretary said that more than two-thirds of all papers published by the Institute during the past three years had been on the subject of metallurgy, and less than one-fifth on mining engineering. In response to the argument that the Institute also published papers on geology, chemistry and assaying, he replied that the Institute did not aim to represent geology, chemistry and assaying as such, and that the pressure of papers was so great that the Committee on Publications, as a matter of policy, declined papers on geology, chemistry and assaying unless they related to mining geology and metallurgical chemistry or assaying. Furthermore, there were representative societies on geology, chemistry and assaying, but not a representative society for the metallurgists, although societies had sprung up in recent years which had a large following of metallurgists and divided, to some extent, the interest in metallurgy between themselves and the American Institute of Mining Engineers, although this Institute is still the representative society for American metallurgists as well as for mining engineers.

The Secretary then introduced a suggestion that an autobiographical directory of members be published at an expense estimated at about \$4000, to be covered by sale among members of the Institute. This directory would be classified and indexed and would give some account of the professional experience and activities of each member.

Boston Section, March 15, 1918.—First Vice-president Goodale and Secretary Stoughton were entertained by the Boston Section at the University Club. This was the annual meeting of the Section, at which officers were elected and a detailed account will appear in the *Bulletin* when received from the Secretary. After the addresses by the First Vice-president and Secretary, several members discussed the question of changing the name of the Institute to the American Institute of Mining and Metallurgy. Several questions were asked and some members did not care to express an opinion, as the suggestion was new

to them. Such comments as were made were almost unanimously in favor of granting to the metallurgists some representation in the name of the Institute.

Chicago Section, March 30, 1918.—Details of this meeting are printed on a following page.

Colorado Section, April 2, 1918.—President Jennings, First Vice-president Goodale, and Secretary Stoughton were entertained at dinner at the Denver Athletic Club. Institute policies were discussed in detail and four or five speakers expressed themselves in opposition to the suggestion of changing the name of the Institute to the American Institute of Mining and Metallurgy, on the ground that the old name had been satisfactory for about forty-seven years and that there was a potential value in a name which would be lost by any change. Also that the name metallurgy was not understood by the general public and that the public did not know how to spell it. Furthermore, that the metallurgists were not any more entitled to representation in the name than were those members of the Institute who were chiefly interested in geology, chemistry, and assaying.

Salt Lake City, April 4, 1918.—The President, First Vice-president, and Secretary were entertained by more than one hundred members at the Hotel Utah. A most interesting discussion on the relations of capital and labor, instituted by President Jennings, was taken up by several members. The suggestion for the change of name was also discussed and various opinions were expressed. An informal vote was then taken merely for the purpose of getting a tentative expression of feeling on the subject, and resulted in a slight majority in favor of the new name.

Anaconda, Mont., April 6, 1918.—The President, First Vice-president, and Secretary were entertained by more than fifty members of the Institute at a luncheon at Anaconda, preceded by a visit to the Washoe smelter. At this point the general sentiment was unanimously in favor of the change of name to the American Institute of Mining and Metallurgy.

Montana Section, April 6, 1918.—The President, First Vice-president, and Secretary were entertained at a dinner and meeting of the Montana Section at the Silver Bow Club, Butte, and a meeting of unusual professional interest was held. In addition to the discussion on the relations of capital and labor, Judge E. B. Howell read a very thoughtful paper entitled "Industrial Organization after the War," which is published on a following page of this *Bulletin*. Mr. Frederick Laist gave a most interesting account of the plans of the Anaconda Copper Mining Co., for the production of ferro-manganese at Great Falls from the manganese ores of Montana. A more detailed account of the meeting will be found on a following page. Several members discussed the question of change of name and there was none present who opposed changing the name to the American Institute of Mining and Metallurgy.

Columbia Section, April 8, 1918.—First Vice-president Goodale and Secretary Stoughton were entertained by the Columbia Section at a dinner and meeting at the Davenport Hotel, Spokane, Wash. The President having been prevented from going, the Institute activities in the war were discussed by the First Vice-president and Secretary, while several members gave interesting accounts of professional activities. None of those present opposed the change of name of the Institute.

Puget Sound Section, April 10, 1918.—First Vice-president Goodale and Secretary Stoughton were entertained at a dinner and meeting of the

Puget Sound Section at the Rainier Club. In addition to the addresses of the First Vice-president and Secretary, the paper by Judge E. B. Howell, which had been presented at Butte, was read by Darcy C. Bard. The suggestion of change of name of the Institute was favorably received by all those who spoke, and none of those present was in opposition to such a change.

St. Louis Section, April 15, 1918.—The Secretary of the Institute attended the dinner and meeting of the St. Louis Section at the Mercantile Club. This was the annual meeting of the Section for the election of officers and a detailed account will be given later. A number of interesting speakers were present. Those who discussed the change of name were in its favor and the usual question developed the fact that no one present was in opposition.

ADDRESS OF PRESIDENT SIDNEY J. JENNINGS

My predecessor in the office of President of the Institute started a custom of visiting the various local sections, thus obtaining their points of view and their ideas as to how the Institute can best serve the interests of its members. Exceedingly valuable exchange of ideas was thus brought about. I am following this custom as far as the limited amount of free time at my disposal will allow me, and I trust that my successor in office will appreciate the benefit to be derived from following the custom thus initiated and will continue the swing around the circle of the local sections.

The activities of the Institute are increased by the prestige gained from large numbers and I trust that every member of this local section will consider himself a member of the committee on increase of membership and will see if he is not able during the coming year to gain at least one new member for the Institute. This is a perfectly possible proposition for, although the membership of the Institute is at present approximately seven thousand, I feel sure there are at least seven thousand more men in the United States who are interested in mining, metallurgy or geology from the metal-mining point of view who would make admirable members or associate members of the Institute.

The first consideration of the Institute as a body, and of each member as an individual, is to win the war and defeat the Huns.

In order to accomplish this, the Institute, as a body, has coöperated with the other national engineering societies and the great bureaus of the Department of the Interior, the United States Geological Survey and the Bureau of Mines in forming committees to study and advise the Government on pressing problems of vital importance.

The Naval Consulting Board was one of the first committees so formed and the Institute appointed two past presidents—Mr. W. L. Saunders and Mr. B. B. Thayer—as its representatives on that board. Mr. W. L. Saunders acts as vice-chairman and presides at the meetings of the board. The Naval Consulting Board has asked the coöperation of every engineer in solving some of the problems that have arisen during this war, notably the problem of dealing with the submarine. It received so many suggestions that it was necessary to form another committee to deal specially with these schemes so submitted, and a committee entitled "War Committee of the Technical Societies of the Engineering Council" was formed

under the chairmanship of one of your past presidents—Mr. D. W. Brunton—to consider all the schemes suggested and to pick out those which they considered should be further developed, and to recommend these schemes to the Naval Consulting Board, who would, thereupon, if they so desired, order some trial of the scheme to be made. Work of this War Committee of the Technical Societies of the Engineering Council has at times been extraordinarily heavy, as many as 1200 letters being received in a week containing suggestions for winning the war.

The War Minerals Committee was formed by appointing a representative from your body, a representative of the Association of State Geologists, a representative of the United States Geological Survey and a representative of the United States Bureau of Mines. This committee was formed to study the possibilities of stimulating the production of certain minor, but essential, minerals in the United States, these minerals having been imported in large measure from foreign countries. The chief of these minor minerals were manganese, pyrites, graphite, antimony, magnesite and quicksilver. The War Minerals Committee did exceedingly good work in getting together and tabulating a great amount of information regarding the quantity of these minerals that we consumed in the United States and the different deposits in the United States which could be developed to supply the needs of industry. After devoting several months to this study the War Minerals Committee came to the conclusion that it was desirable to have additional legislation, based on the lines of the food act, which would appoint a Metals Administrator with similar powers to those of the Food Administrator. In this conclusion they were backed by the belief of the heads of the Department of the Interior, United States Geological Survey and the Bureau of Mines. The chairman of the War Minerals Committee—Mr. Westervelt—together with Mr. George Otis Smith and Mr. Van H. Manning attended a meeting of the Board of Directors and laid before them the arguments in favor of this legislation. After a great deal of discussion, extending over three meetings of the Board of Directors, a vote was recorded by the Board in favor of supporting this legislation and a committee, consisting of your President, your First Vice-president, and Secretary, was appointed to visit Washington, at the request of Mr. Manning, and see for themselves the difficulties encountered by the War Minerals Committee and the necessity for the legislation proposed to meet those difficulties. This Committee went to Washington and visited those members of the different boards who were specifically interested in this problem and then they had a joint meeting with representatives from these different boards, presided over by Secretary Lane. This meeting included Senator Henderson from Nevada (Chairman of the Senate Committee on Mines), Representative Foster (Chairman of the House Committee on Mines), Mr. Hoover of the Food Administration, Mr. Wooley of the War Export Board, Mr. Gay and Mr. Leith of the Shipping Board, Mr. Pope Yeatman of the War Industry Board, Otis Smith of the United States Geological Survey, Mr. Van H. Manning of the Bureau of Mines, Mr. Callbreath, Secretary of the American Mining Congress, Mr. Westervelt and Mr. A. P. White of the War Minerals Committee.

As each one of these gentlemen expressed his belief in the necessity of immediately stimulating the mining industries so that the shipping that had been utilized for the importation of the tonnage required could be released for the export of food stuff to our Allies and men in our fighting

front, the necessity for the legislation asked for impressed itself vitally upon the committee of your Board of Directors. As one gentleman expressed it, all the Boards recognized the importance of this question and were willing to coöperate in it, but unless there was some grand "follower-up" whose duty, second to that of winning the war, was to see that these metal industries were stimulated, the promises of the various Boards would be forgotten or pigeonholed and the new industries would die or be taxed out of existence. The committee of your Board expressed itself in favor of the legislation provided some means could be adopted by which these new metal industries could have their fair share of the labor supply. It was pointed out by your committee that when you imported manganese ore or pyrites you, at the same time, imported the labor that had been spent upon mining and transporting that ore, and that when you were going to rely upon the developing in the United States of new deposits you would require an additional amount of labor of which there was none too much at the present time. The bill as drawn up was taken up by the Committee on Mines of the House and evidence in its favor was given by Secretary Lane, Mr. Baruch of the War Industries Board, Mr. Pope Yeatman and also by your Secretary.

Some of the members have objected that this action of your Board was dragging the Institute into politics. I don't agree with that criticism, as it seems to me that the sole desire of your Board and the only result of the action taken by its committee was to further the interests of the mining industry with which the Institute is so closely associated.

Another of the activities of the Institute was to form, in coöperation with the Bureau of Mines, an index of the experience of its membership and their availability for governmental work. The other national engineering societies also formed a similar index of their membership and, at the present time there is a card catalog of some 33,000 names, with a list of their qualifications and experience, from which selections can be made whenever the Government requires the nomination of men for service in various branches of governmental work. This is done frequently and sometimes on a large scale, as quite recently some 600 engineers were asked for by the Government at one time, and names were supplied in very short order. During this trip West I have received a request from the Navy Department to nominate twenty-five men for work as submarine engineers, and I am telling you this at the present time so that, if anyone within the sound of my voice either desires for himself such employment or knows anyone to whom he thinks such employment would be acceptable, he may pass the word along and send in his name to the headquarters of the Institute in New York. The requirements of the Navy for this position are fourfold:

First, that the man should desire to be a submarine engineer;

Second, that he shall hold a degree as a mining engineer, electrical engineer or chemical engineer;

Third, that he shall have had two years' experience since receiving his degree;

Fourth, that he shall be sound physically, mentally and morally.

Should the Navy Board accept a nomination, the man so accepted will have to undergo a period of intensive training, during which time he will have the rank and pay of an ensign in the Navy.

We can look forward with confidence to the fact that the war will be won by us and it behooves the Institute as a body now to take into con-

sideration and discuss the problems that will arise after the war is won. The hearts of men are now being tried and they will instinctively search out and inquire into all the devices which they have used in the past for government, for business or for any joint or communal action. I am convinced that out of the welter of this world war a classified society will emerge, where all shall have equal rights before the law and where the opportunity for merit to advance will be unlimited and unimpeded by any action of the community. The relationship between the "haves much" and the "haves less" is in the yeasty ferment of life and it behooves us carefully to consider the possibilities of this relationship and give our aid and services toward its proper expression.

The old personal relationship between employers and employee has largely disappeared and in place of the employer the company with limited liability has grown up.

The company is a conception of the Roman law. In their time they had the collegium and corporati which corresponded exactly to our company and stockholders. They had a common fund and could pursue a common object. In modern times the English are the nation which adopted this conception of joint stock companies in the largest degree and the number of companies grew to such an extent that an act called "the bubble act" was passed in the English parliament in 1719 which declared joint stock companies to be public nuisances. In 1855 the conception of limited liability, whereby the liability of the stockholder was limited to the amount he subscribed for shares, was introduced by the English parliament. In 1862 the "consolidated companies" act was passed by the English parliament under which the tremendous growth of companies and corporations has taken place both in England and in the rest of the world.

The company owes its vitality to the coöperative principle by which a multitude of small investors create a fund to be used in the furtherance of a common object. This device has admirably served the purpose of absolutely and unmistakably determining the division of profits resulting from the joint action of those contributing to the fund.

The substitution of the company, which has been defined as a legal entity without a body to kick and no soul to damn, for a personal employer has, however, had certain tendencies which, when pushed to an extreme, have led to undoubted abuses on three classes of society. First, investors. Investors in a company with limited liability may entirely divorce the responsibility of how wealth is acquired from the actual possession of wealth. They thus tend to lose touch with their fellow men. Second, managers are given great power with only a limited amount of accountability. Human nature cannot stand either too much prosperity or too much power and unless managers are called to account for their stewardship they lose their sense of proportion and their sympathy with their fellow workers. Third, laborers: under company management, laborers tend to become cogs in a big machine and lose incentive to do their best. The human will is one of the most illusive of things, but the difference between having it work for you or against you is all the difference between success and failure. This fact has been most strongly brought to my attention by the statements of recent visitors from England who were interested in the labor problems there as they have been developing during the war. Statements were made by several manufacturers that partly trained women who were keenly

desirous of doing their best would produce from three to four times as much work as had previously been produced by skilled men who were only desirous of doing enough not to be dismissed.

Many methods have been suggested of correcting the above abuses which are admitted by most thinkers. Publicity of stock ownership so that each individual shareholder could know who were his co-partners in any enterprise is one of the suggestions that seems to me to promise much toward placing the responsibility of the company's action where it belongs, that is, upon the stockholder. The requirement from the management of periodic reports to stockholders, giving a detailed account of their stewardship, will be corrective of many of the abuses of management. One of our largest corporations, the United States Steel Corporation, under the leadership of its chairman, Mr. Gary, has put in operation a plan for interesting its laborers in the success of the corporation by making them shareholders therein, which promises good results. Other corporations have found that their annual payroll was approximately the same as the capital necessarily employed in their business and the managements have decided that, after paying what they called the wages of capital—say 6 per cent., any profit above that will be divided equally between capital and labor, and thus so-called labor dividends are declared. A further suggestion for inducing the human will of the laborer to co-operate with the director in the success of an enterprise is the use of an employment manager. Considerable discussion has taken place on this subject and the results obtained in several plants have been reported to the Institute, but the suggestion seems to me fertile and capable of further expansion. We are no longer buying labor; we are selling employment, and our salesmanship is somewhat defective and must be improved. We no longer have a reservoir of idle hands from which to draw our laborers and the days of "hiring and firing" are limited. Every man who is hired by a corporation is supposedly capable of working, certainly is desirous of working, and has the ultimate necessity of working in order to earn his living; therefore, it behooves us to find out where his capabilities can be profitably utilized and not merely allow the whim or temperamental objection of some foreman or the misunderstanding of the man himself to entail upon the company the large expense attendant upon the continual change of laborers.

I am one of those who think that the interests of capital and labor are identical, up to a certain point. They both want to produce wealth and they both realize that in order to produce wealth they must co-operate. It is only when it comes to dividing that wealth that their interests apparently diverge. For me, the ultimate basis of value is the emotion aroused in a person by the possession of the thing valued. Money is the most common, but it is by no means the only, yardstick by which the arithmetical expression of value can be made. If you have in one hand something that you value and a person offers you something else for it—be it either money, fame, renown, honor or any other valuable thing in this world—you will take that which is offered you in the other hand and when that which is offered you arouses a greater emotion in you than that which you have, you part with that which you have and take that which is offered you. Recently a member of the Institute, and a friend of mine, came to New York and went through some of the large houses in New York where are accumulated treasures of our art, of our skill and our culture. He also went through, from top to bottom, many

of the large department stores where goods of all kinds are gathered together to please the eye and mind and pallet of men and women, and after seeing all this he came to the conclusion that the vast bulk of it was burdensome trash. Here is a state of mind with which we shall have to reckon when the war is over. We have got to realize now that much of what we now call wealth will seem to those returning men from the front nothing but burdensome trash.

Sit down with labor and its representatives and find out what it wants. Some of these men are reasonable; some are unreasonable, just as it happens in every other class. Don't let the laborer, partly for want of understanding on our part—we who form the captains, lieutenants, sergeants and corporals of this great army of labor—fall into the hands of extremists who will lead him into every kind of mirage pictured by the Bolsheviks.

The Institute is primarily a forum to discuss and clarify ideas, and in order to bring this problem of human engineering more prominently before the Institute I have appointed a committee on Industrial Organization which has divided the work among various sub-committees.

WAR ACTIVITIES

ENGINEERING FOUNDATION

Annual report for third year, ending February 28, 1918

During the year terminating at the date for the third annual meeting of Engineering Foundation, the Board completed its undertaking to sustain the National Research Council for one year. Assistance given in the organization of the National Research Council has been amply justified by the results. The Council is now well established in a 4-story building at 1023 16th Street, N. W., Washington, and has recently secured another similar building near by in order to house its increasing force. The breadth, importance and volume of work done have steadily grown. Foreign offices have recently been established in London and Paris, Dr. H. A. Bumstead being in charge of the former and Dr. William F. Durand of the latter. The total expenditure by Engineering Foundation for the National Research Council was \$9,036, derived partly from income of the endowment fund and partly from special gifts from Ambrose Swasey and Edward D. Adams.

In May, Walter M. Gilbert was appointed Assistant Secretary of Engineering Foundation, with headquarters in Washington, his services being contributed by the Carnegie Institution. He also became and has remained to date Assistant Secretary of the National Research Council. In September, resolutions were exchanged between the Engineering Foundation Board and the National Research Council, setting forth a policy of continuing reciprocal relationship, and a conference committee, Chairman M. I. Pupin, Dr. Charles Warren Hunt, and Gano Dunn, was appointed to inform the National Research Council of the readiness of Engineering Foundation to work upon definite problems suggested by the Council. No problems have yet been suggested.

This achievement of the Engineering Foundation Board in establishing National Research Council and maintaining relationships with it, is believed to be the first successful attempt to put engineers and scientific

men in close touch for the carrying out of a comprehensive program, involving both research and engineering.

M. I. PUPIN, *Chairman.*

FIRST REPLACEMENT REGIMENT OF ENGINEERS

The German Kaiser is employing the keenest engineering talent of his own and allied empires in his attempt to defeat the world. American employers are paying engineers such attractive salaries that voluntary enlistments of high-class technical men in the United States Army are below requirements. This deficiency is also probably due in part to the lack of proper information concerning the engineering branch of the service. Few civilians know that it is possible for them to perform in the Engineering Corps almost exactly the same kind of work as that in which they are now engaged.

The best results in any organization are obtained only when the energy of every man in it is concentrated along the line for which he is best suited by natural ability, education, and training. It is more important to have the right man in the right place in our Army, where lives of men are at stake, than it is in any business enterprise. The First Replacement Regiment of Engineers was organized at Washington Barracks, D. C., on Dec. 14, 1917, with the express idea of accomplishing this end. Its specific purpose is to keep all engineering units of the Army at full enlistment strength during the period of this war. This regiment has not only the responsibility of finding men to fill depleted ranks, but it must also fit them to step into the work of trained, efficient and disciplined soldiers.

The preliminary work of the recruit is first a thorough training in military drill, for the engineer soldier must be prepared to lay down his shovel and take up his rifle at any time. Infantry drills gradually give way to engineer work and more specific technical training. The engineer soldiers must know how to tie knots and lashings, to build spar and truss bridges, to construct revetments, dig trenches, place wire entanglements, construct machine-gun emplacements, build pontoon bridges, and to construct roads. They must also know the methods of demolition, sapping, and mining. Specialized training in lithography, zincography, surveying, mapping, photography, carpentry, blacksmithing, electricity, and machinery, are also given to those qualified for further training in any of these branches.

Engineers are called upon to perform such a wide range of work that practically every man with any technical training or mechanical ability can find a place in this organization. Every male citizen in the United States who is physically fit, and between the ages of 18 and 21, and 31 and 40, is eligible to join the regiment by voluntary enlistment.

To be assured of assignment to this Regiment, the applicant for enlistment should write to the Commanding Officer, 1st Replacement Regiment Engineers, Room 107, Headquarters Building, Post of Washington Barracks, D. C., for an application blank. If the blank shows the man to be eligible, an enlistment card is filled out and sent to the Recruiting Officer nearest to the applicant's place of residence, with instructions to enlist the man for service in this Regiment. Transportation

and meals will be furnished by the Recruiting Officer and the man will be instructed to report at the Post for duty.

It is important that the applicant comply with these instructions closely, as otherwise it may be found impossible to effect a transfer to the organization after enlistment.

ATHLETIC SUPPLIES FOR THE 602D ENGINEERS

We are advised by Second-Lieutenant Maxwell E. Erdofy, a member of the Institute, and athletic officer of the 602d Engineers, stationed at Camp Devens, Mass., that his regiment, representing all branches of the engineering profession, is in need of athletic equipment and supplies. The regiment will highly appreciate any assistance in the way of financial contributions, or of apparatus and equipment for their athletic needs.

WOMAN'S AUXILIARY

NEW YORK SECTION

Meeting of April 6, 1918

The House Committee of the Engineering Societies Building has lent to the members of the three welfare committees a room on the ground floor of the building where they can carry on some of their war activities. Two sewing machines and two knitting machines are installed there and ladies are invited to sew for the Foreign War Relief Committee and knit for the Emergency Committee, which is working for the 27th Engineers, a special mining regiment.

The *Emergency Committee*, Mrs. H. Norman Spicer, Chairman, reports the formation of a committee of 21 members. The organization meeting was held March 7, and plans were made for future activities as follows:

A letter was read from Mr. Ingalls asking for 72 sweaters, 72 helmets, 66 pairs of wristlets as well as 772 pairs of socks, 272 being for immediate delivery. To meet this request it was decided to secure the helmets and wristlets from the Navy League, and to undertake the making of the sweaters and socks ourselves. Accordingly Mrs. H. N. Spicer and Mrs. J. H. Devereux were empowered to buy wool in sufficient quantities, and woven material for the 72 sweaters, sending the bills to Mr. Ingalls, who had guaranteed the money from the *Engineering and Mining Journal*. This was attended to promptly, and the materials were ready for distribution to the committee on March 13.

After considerable difficulty, knitting machines for the socks were discovered and the agent came to demonstrate them. Mrs. Spicer gave one to the Committee and Mr. Ingalls has guaranteed the money to buy two when the manufacturers can deliver them. Up to April 6, 130 pairs of socks, machine and hand-knitted, have been handed in—also 68 sweaters, 80 helmets and 90 pairs of wristlets. It has been calculated that it needs five women knitting behind each man at the front to keep him continuously supplied with knitted garments.

In order to increase our funds, the committee has decided to give a concert on Sunday, April 21, at the Hotel des Artistes.

The Committee is interested in the work, and consequently very active.

Laura Spicer, *Chairman*.

The Foreign War Relief Committee, Mrs. H. H. Knox, *Chairman*, reports that the Foreign War Relief Committee was formed on Feb. 2, 1918, with 14 members.

At the first meeting it was decided to send to the Commission for Relief in Belgium the sum remaining in the treasury of the Belgian Relief Committee, amounting to \$637.72, thus closing the account of the Belgian Relief Committee.

In view of the needs of the devastated districts of Northern France, the committee undertook as its initial effort to raise money for the purchase of sheep for the Aisne District, to be given through the American Fund for Devastated France. Letters were sent to the 63 members of the Section residing in or near New York, and a lecture was given in the Auditorium of the Engineering Building by a member of the Civilian Committee. In response to these appeals, the sum of \$461 has been received. An appeal will be sent to the 800 members of the New York Section of the A. I. M. E. for this fund.

Through the efforts of Mrs. A. O. Ihlseng and H. W. Hardinge, four lectures on the war have been arranged for and will be given in April.

The Committee is also making clothing for the women and children of devastated France, and will be glad if ladies will come and sew at the workroom on the ground floor of the Engineering Building, at 29 West 39th Street, on Wednesday and Thursday each week.

Sophie C. Knox, *Chairman*.

LOCAL SECTION NEWS

CHICAGO SECTION

Charles H. MacDowell, *Chairman*, Luther V. Rice, *Vice-chairman*,

Henry W. Nichols, *Secretary-Treasurer*,

Field Museum of Natural History, Chicago, Ill.

Alexander K. Hamilton,

G. P. Hulst,

Henry P. Howland,

Frederick T. Snyder.

A meeting of the Chicago Section was held at the Chicago Engineers' Club on the evening of March 30, 1918, on the occasion of the visit of the President, Vice-president and Secretary of the Institute. The meeting was called to order by Henry W. Nichols, Secretary of the Chicago Section. The first speaker of the evening was Mr. Allen, Deputy Fuel Administrator for the State of Illinois, who spoke on the problems and difficulties encountered by the Fuel Administration during the past winter. He paid high tribute to the spirit of coöperation shown by the

coal producers of Illinois. Mr. Allen pointed out that the principal problem in Illinois, as elsewhere in the United States, was the difficulty of transportation; at times not more than one-fourth of the normal number of cars were available for shipping coal. As for the future, Mr. Allen outlined the system of zoning the coal producing and consuming territories, from which the most helpful results are anticipated. Mr. Allen also emphasized the necessity of encouraging consumers to lay in their winter's supply during the coming summer.

Dr. Honnold, of the Federal Fuel Administration, gave further explanation of the zoning system and further urged that consumers lay in their winter's supply as early as possible, the prices now having been fixed by the Fuel Administration. Dr. Honnold also referred to the shortage of labor in coal mines entailed by drafting into the army. In answer to a question as to why the canals of Illinois were not utilized for the distribution of local coal, Dr. Honnold explained that this was impracticable on account of the excessive breakage of the brittle coals of Illinois under the repeated handling necessitated by this method of transportation.

Mr. Traylor, speaking of the coal industry from the points of view of production, transportation, and distribution, also emphasized the importance of early storage of next winter's coal in order to relieve congestion on the railroads. Mr. Traylor then mentioned that the western coals are somewhat at a disadvantage on account of their high proportion of moisture and volatile components, which tend to make the combustion of these coals rather inefficient when burned in boiler furnaces of the usual eastern type. Mr. Traylor then spoke at considerable length on a method of transforming these high-volatile coals into a smokeless fuel, an industry with which he has recently become associated.

Mr. Ede, continuing the discussion of utilization of coal, attributed most of the inefficiency to incorrect methods of firing boilers, and urged that consumers instruct their firemen in the proper method of fuel consumption.

Professor Stoek mentioned the fact that large numbers of modern apartment houses in Chicago are equipped with boilers designed for burning Pocahontas coal, as an outcome of agitation to prevent the pollution of Chicago's atmosphere by coal smoke. Now that Pocahontas coal is almost eliminated by its long haul, considerable difficulty is anticipated in converting the boilers to the use of local soft coal.

President Jennings then addressed the meeting, speaking first of the several lines of activity in which the Institute is assisting the Federal Government in the prosecution of the war. He mentioned first the work of the War Minerals Committee, and the proposed bill for Federal control of certain minerals. He spoke also of the War Committee of Technical Societies of the Engineering Council and outlined the nature of its work. He mentioned also the advantages that had accrued from the compilation of the personnel list by the Institute and by the Bureau of Mines. Looking forward to the end of the war, President Jennings urged that all employers and managers of labor should devote careful thought to a more rational and humane adjustment of the relations between employers and laborers.

"The whole problem of capital and labor is going to come up in a more acute form, and we must think out and decide on some sort of solution. With foresight, we probably and almost certainly shall be able to escape

some of the excesses that have taken place in other countries less free than ourselves to express opinions, less educated in self-government."

In conclusion, President Jennings referred to the desirability of a greatly enlarged membership of the Institute, and urged every member to try to interest other persons in the organization.

Vice-president Goodale, in continuation of the fuel discussion, mentioned the fact that by the use of pulverized coal it had been possible greatly to reduce the consumption of fuel in the reverberatory smelting of copper ores in Montana. He next alluded to the work outlined by the newly created Committee on Industrial Organization, and pleaded for better treatment of workmen in the United States, particularly those of foreign origin. He believes that a more rational and humane treatment of these workmen will go far toward offsetting the pernicious influence of the I. W. W.

Secretary Stoughton, speaking of the patriotism with which members of the Institute offered their service in the early stages of the war, at which time offers of service were far more numerous than opportunities for utilizing them, stated that conditions are now exactly reversed, and there are not enough workers to carry on the greatly multiplied duties of administration. The need of younger mining engineers is particularly felt in the Ordnance Department and in the National Research Council.

Secretary Stoughton, discussing internal affairs of the Institute, referred first to the recent changes in the requirements for admission to membership, and then introduced the proposed change of name to American Institute of Mining and Metallurgy. He next spoke of the proposal to issue an autobiographical directory of members of the Institute, compiled from the results of the questionnaire issued to the membership three years ago.

Mr. Stoughton was followed by a number of speakers, all of whom appeared to be in favor of the proposed change of name, but pointed out that a majority of the members of the Chicago Section were metallurgists, and that therefore their opinion might be somewhat one-sided.

Mr. E. C. Johnson, reverting to the topics under consideration earlier in the evening, mentioned his experience in the introduction of pulverized coal as a matter of fuel economy, particularly in connection with the metallurgy of iron and steel. He also looks forward to the necessity for an amicable adjustment of difficulties between labor and employers, and recommended the more extensive adoption of the contract system as a satisfactory solution of these problems.

The matter having been introduced by the Chairman, on motion duly seconded, it was voted to appoint representatives from the Chicago Section to form a joint committee with members of the Western Society of Engineers, to hold meetings in Chicago for the discussion of topics of interest to mining engineers, more particularly in connection with the present war activities.

The meeting then adjourned.

HENRY W. NICHOLS, *Secretary.*

MONTANA SECTION

N. B. BRALY, *Chairman*,B. H. DUNSHEE, *Vice-chairman*,E. B. YOUNG, *Secretary-Treasurer*, 526 Hennesey Building, Butte, Mont.

F. W. BACORN,

C. D. DEMOND.

Special Meeting of April 6, 1918

On the call of the Executive Committee, the Montana Section held a meeting on the evening of April 6, 1918, at the Silver Bow Club, Butte, Mont., following dinner which was attended by 69 members and guests.

The meeting was called to order by Chairman N. B. Braly, who explained that the purpose of the meeting was to welcome the officers of the Institute and to discuss Institute policies and interests. He then introduced President Sidney J. Jennings, who spoke at length on the details of coöperation of the Institute with the Government in the war, and on industrial reorganization which may come after the war. First Vice-president C. W. Goodale spoke on the work outlined for the new Institute committee on "Industrial Organization." Secretary Bradley Stoughton spoke of the need for engineers in the Government service, and explained that the Institute was now in a position to aid members in securing suitable patriotic service. He told of the proposal to change the name of the Institute from A. I. M. E. to American Institute of Mining and Metallurgy. Subsequent discussion by C. H. Bowman, E. H. Wilson, and Sam Barker indicated approval of the suggestion; no objections were offered. Mr. Stoughton also spoke of the project of publishing an autobiographical directory of members of the Institute.

Former President James F. Kemp spoke on the work of the engineers in the solving of problems connected with the war, and of the causes of the war as seen from the standpoint of a mining engineer. Hon. E. B. Howell, upon invitation, delivered a paper on "Industrial Organization after the War." R. H. Sales spoke on the proposed bill for Federal operation and control of mines producing the rarer minerals. President Jennings followed with a discussion of the history of the bill, its purposes, and the necessity for its passage. Frederick Laist spoke on the plant now in course of construction at Great Falls for the production of ferromanganese, and on the proposed methods of treating manganese ore.

The report of the Anaconda Woman's Auxiliary was read by Secretary E. B. Young. On motion, it was voted that the Section express its appreciation to the Silver Bow Club for the use of the club rooms for the meeting. On motion, a vote of thanks was given to all the speakers of the evening for their coöperation in making the meeting a success. The meeting then adjourned.

E. B. YOUNG, *Secretary*.

Industrial Reorganization after the War

HON. E. B. HOWELL.—It is generally assumed that there will be radical readjustments of social conditions after the war. What the new alignment will be must depend very largely on whether German Kultur or American democracy prevails. At this moment on the plains of

Picardy your future, my future, and the future of America, are hanging in the balance. Shall the United States remain a free nation with its face toward the sun of a brighter day, or shall it be a subjugated and humiliated nation, under tribute to the Kaiser; that is the question which the war is about to decide, and it behooves every American citizen to hope, help and pray for the success of our arms and those of our Allies.

In considering the probable industrial developments of the future, it will assist in clarifying the problem to consider what have been the industrial developments prior to the war. One hundred and fifty years ago the manufacturer was a person who made things by hand—by his own hands usually. He was the weaver by his loom, or the smith at his forge. If he prospered, he hired other workers who were called “hands.” Why should they have been called “hands” rather than “heads?” For the simple reason that the boss was retaining the head-work, or management, for himself. The wage-earner was simply a hand. He was not expected or permitted to advise the management.

So long as the organization of industry was primitive and simple, this divorce between the manual worker and the management occasioned no trouble. The greater bulk of the population was agricultural anyway, and people living close to mother earth and directly deriving their sustenance therefrom have never bothered their heads with complicated industrial or social problems.

But with the invention of the steam engine there came a great change in industry. The single loom was multiplied by hundreds. The forge was replaced by furnaces and steam hammers. The manufacturer ceased to work with his own hands, and usually was a corporation. The number of hands employed was multiplied by hundreds and thousands. But there was one feature of the original primitive system that remained and has persisted to the present day—the manufacturer retained the management, the hands remained mere hands.

Several years ago I wrote an article for an eastern journal entitled “Labor vs. Capital vs. Management,” in which I tried to develop the thesis that management is a third element in the industrial conflict that should not be identified with either capital or labor. Often the capitalist has his grievance against the manager quite as well as the laborer.

I think that if we bear in mind this third element of management, it will assist in clarifying the industrial problem. When one thinks of it, there is no reason in the nature of things why the people who furnish the capital to inaugurate an industry should manage it to the entire exclusion of those who have invested their manual skill therein. The latter have quite as vital an investment as the former. If the manual workers were in control and should tell the capitalist, *à la* Bolsheviki, that he was fired, that he could “go chase himself,” or similar terms implying that his connection with the establishment was at an end, that capitalist, so fired, would have much the same feeling that a workman has who has been discharged from the only industry that he knows anything about, and perhaps faces the necessity of selling out his little home, and emigrating.

The industrial labor problem will never be solved until the right of the manual worker to share in the management of industry is recognized. It will never be solved until the wage-earner has some kind of a contingent financial interest in the enterprise. As it is now, there is continual

warfare between labor, unions and their employees, sometimes suppressed only to break out again. The labor unions demand the highest possible wage, seemingly thinking that they are entitled to all that they can persuade or extort out of their employers, regardless of whether the business can stand it or not. Where the employer is compelled to pay the highest wage, he immediately recoups his loss from the general public, part of whom are the very wage-earners, by advancing the price of the commodity manufactured. The labor union seeks only to get as much as it can of the fruits of the industry for as few hours' work as possible. It does not assume any of the burdens of making ends meet, of finding a market for this product, and of securing competent and faithful employees, that the employer has to shoulder.

The ordinary employer regards the efforts of labor union as an unwarranted interference with his own private business. He by no means recognizes the right of the manual worker to any part in the management of the industry. He has the feeling of the employer for centuries past: "I put up the money for this enterprise, I own it and have the right to manage it as I choose without interference."

The fallacy in this position does not appear where the employer hires only one or two hands. It begins to appear when he begins to monopolize a great industry in any particular place, and hires hands by the hundred or thousand. Then it begins to be apparent that he does not own the industry in the full sense of the term, that the State has an interest in the industry and in the welfare of the workers dependent on that particular industry for the livelihood of themselves and their families.

When we recognize the interest of the State in industry, when we see that the workers who have acquired a manual skill therein have a real and substantial investment, then it follows inevitably that the exclusive management of industry by capital must sometime have an end. Industry must become of the people and for the people just as surely as government itself.

After the war, I believe that labor will participate in the management of industry. I use the word "participate," because I do not believe the plan of socialism to exclude capital, or to exclude those captains of industry whom we call the management, will ever succeed anywhere, or ever even be tried in America. The Bolsheviki are giving an object lesson on this subject to the whole world.

But the participation of labor in the management will solve the problems not only of labor but of capital. This participation will not come as a gratuity like so-called profit sharing. It will come as the manual worker's right—as the restoration to him of the birthright that unawares he lost when the steam engine brought about a transformation of the industrial world in the eighteenth century.

I can imagine the keen, highly trained manager at this point objecting: Must I associate with me in my work the unlearned, untrained, irresponsible and sometimes dissipated men that come to me for work? Must I take orders from such men as these? And the capitalist may protest that his property should not be put at the mercy of employees.

In every industry, there are probably employees who are unfit to participate in the management, but even their own comrades would not choose them for such a purpose. On the other hand, in every industry

there are manual workers as intelligent, as fair-minded, and as just, as many of those now controlling industry.

When labor acquires a contingent interest in industry it will be to the interest of the manual worker to help the enterprise to succeed. He will be an enemy of the slacker and shirker because the latter lessens his profits. He will be loyal, because loyalty will increase his own profits.

While I am sure some such change in industry is coming, I do not know just how it will come. Progress is wrought out quite as much as thought out. Perhaps it may come about by the creation of a new kind of stock for the corporations employing many hands, which one might call "industrial" stock. Capital stock would go to the men furnishing the capital and industrial stock be set aside for those furnishing the manual skill and the brawn. Each kind of stock would have its representatives on the board of directors, and each would share in surplus profits. I use the term "surplus profits" because there must first be paid out of gross earnings a reasonable wage to labor, a reasonable salary to the manager, and a reasonable interest on the money invested. These payments might absorb all the net earnings, but every successful corporation has its prosperous years when there is a melon to cut, and then the industrial stock would come in for its share of the extra dividends.

Popular government may not always have as efficient officers as autocratic government, yet none of us would for that reason want to go back to autocracy. What a democracy loses in efficiency it gains in a greater diffusion of well-being, and in the loyalty of the governed.

An industry managed in part by its operatives may lose some of the cold-blooded efficiency of an industry managed by one autocratic mind, but if it ministers to the welfare of a greater number of people, if it substitutes loyalty for disloyalty, hope for despair, the honest toiler for the shirker, industrial peace for industrial warfare, then it marks progress.

Compensation for industrial accidents, sick benefits, old age pensions, settlement workers, social surveys—all of these things have their use, but they are in the nature of gratuities—of charity if you please. What the worker wants is not charity but his rights. What are his rights? Is he getting all that he is entitled to of the profits of industry? Has there been a just distribution of wealth?

I have written this paper on short notice and hurriedly. It is intended to be suggestive, something to set you thinking and something to provoke discussion perhaps, rather than an elaborate argument. I have not had time to sugar-coat the pill, and perhaps some of you will be unwilling to swallow it. But if you do not like this medicine, what cure would you suggest for the existing social malady? The socialists are proposing a definite program. What program have you?

Do you realize what is the great cause of causes lying back of the social unrest, and back of the war itself? It is gold—a great deluge of gold. During the first 17 years of this century there was as much new gold produced as during the entire last half of the nineteenth century, which included all the gold production of the placers of California and Australia. The gold production of these last 17 years was probably greater than that of any thousand years of the world's history preceding 1850. The average annual production of gold during these 17 years has been many

millions greater than the combined production of gold and silver in 1896, estimating the value of the silver at a coinage ratio of 16 to one.

What is the significance of this deluge of new gold? Do you know what a boom mining camp is like—when money becomes plentiful and cheap, when wages advance, when anything in the way of property can be sold, and when prices are continually advancing and everybody has money to spend? Something like that has happened on a world-wide scale during the twentieth century as the result of this deluge of new gold. All the elemental passions and all the frenzied finance of a new gold bonanza camp have been let loose in the whole world. Indeed the whole world has assumed the aspect of a new boom gold camp.

Of course the new wealth thus created was not evenly nor equitably distributed. It never is. But the sight and knowledge of the great fortunes being made created the same discontent that the unsuccessful miners in a gold camp must have when they see their more successful fellows go out with more gold than they know what to do with. The conditions I have outlined are unprecedented in the history of the world. They have produced unprecedented evils, and these evils will probably be remedied by a cure in many respects unprecedented.

SAN FRANCISCO SECTION

A. C. LAWSON, *Chairman*, ROY H. ELLIOTT, *Vice-chairman*,
W. H. SHOCKLEY, *Sec'y.-Treas.*, 959 Waverley St., Palo Alto, Cal.,
T. A. RICKARD, C. F. TOLMAN, JR.

Meeting of Feb. 5, 1918

A meeting of the San Francisco Section was held on Feb. 5, 1918, at the Engineers' Club, about 35 members and guests being present. The supply of manganese, as affected by the war, was discussed by G. D. Lauderback, Professor of Geology at the University of California, and E. A. Hersam, Professor of Metallurgy at the same university, read a paper on the metallurgical possibilities of the treatment of manganese ore.

Professor Lauderback spoke of the great increase in consumption of manganese because of war stimulation, and the greater use of high-grade ferro-manganese in the open-hearth process, which uses ferro-manganese normally of 80 per cent. Mn, while the Bessemer process uses spiegel with 20 to 30 per cent. Mn. Before the war, the production of high-grade ore in the United States was insignificant (2200 tons in 1910, increased to 33,000 in 1916) while the total importation of manganese ores in 1916 was 576,321 long tons.

Before the war, Brazil (70,000 tons in 1913), Russia (124,337 tons in 1913), and India (141,587 tons in 1913) furnished the bulk of foreign ores here. The total stoppage of Russian ores, and the great diminution of the India supply since the opening of the war, have been compensated by Brazil, from which country we received 471,837 tons in 1916, and proba-

bly more than 500,000 in 1917. But to bring us this supply requires the use of a fleet of ships which are urgently needed to carry men and supplies to Europe.

The main sources of manganese ores in the United States are the nodular and pocket ores of Virginia, Georgia, and Arkansas, and the lenses and veins of California. In the Lake Superior region there are immense deposits of mangiferous iron ores; various states of the interior Cordilleran region (such as Colorado, Montana, Utah, Nevada, New Mexico, Arizona) contain mangiferous silver ores, and total a large tonnage of low-grade material; and some manganese is obtainable from the New Jersey zinc residuum. In spite of the great increase in prices, the United States produced probably not over 8 per cent. of the manganese contained in the high-grade alloys made in 1916.

A larger use could be made of American ores, and the industry made less dependent on foreign supply, if the lower-grade alloys could be in greater part substituted for the standard ferro-manganese in the manufacture of steel. On the other hand, a successful method of concentrating low-grade manganese ores would supply a larger proportion of the United States production in a form suitable for ferro-manganese manufacture. Both of these lines are being investigated.

In California, manganese deposits are scattered widely over the State. They are mostly small, 10,000 tons being considered a large deposit. The chief, practically the only, troublesome impurity is silica. A satisfactory method of utilizing directly, or of concentrating, the more highly siliceous ores would make available for use several times the amount of manganese now marketable. The small size and difficulty of access of many of the deposits, and the temporary, emergency character of the mining industry, which could not continue on pre-war ore prices, have a restraining influence on production. The small producer has difficulty in disposing of his ore, for he cannot guarantee future delivery of definite tonnage or grade. There is a certain hesitancy to invest capital to develop properties, when a sudden stoppage of the war would prevent the return of the investment.

Both of these difficulties would be met by a guaranteed fair minimum price for a period of, say, two years, and by the establishment of buying agencies that would solicit and accept small lots for which cash payments would be made, the lots accepted to be sampled, graded, and made up into larger shipments by the buying agent.

Professor Hersam described his preliminary studies on the beneficiation of manganese ores. California ores are usually low in manganese, high in silica, and laden with gangue minerals; phosphorus is below 0.2 per cent. (the penalty limit). Steel makers demand a 48-per cent. ore, for which \$50 per ton is paid (January, 1918), but the sorting of ores to this percentage is wasteful. Standard concentration by jigs, classifiers, shaking tables and vanners is commercially questionable. Judging by the tests that have been made in the University of California laboratory, with a Wetherhill machine, magnetic concentration is practical; drying or calcining of the ore may be desirable. A recovery of 80 per cent. of the manganese in a marketable product may be expected. Flotation tests have not been favorable; the tailing frequently contained more manganese than the original ore. Electrostatic separation is incomplete and not likely to be important. The chemical extraction of the raw or roasted ore by sulphuric acid seems feasible; recovery of the

manganese by electrolysis contains many elements of success. Professor Hersam believes that the essentials of manganese ore-dressing are careful crushing and dry magnetic concentration; where the orebodies are of sufficient magnitude, chemical extraction may, in certain instances, be found profitable.

C. F. Tolman, Jr., Professor of Geology at Stanford, had investigated the manganese deposits of California with a view to military use; he finds the ores are the result of superficial oxidation. From the standpoint of the manganese miner, the geologist is a dispenser of gloom, for the geologist must say "No" when asked if the ore goes down. The ores are difficult to sort and difficult to treat. In Arizona, Professor Tolman examined a deposit 40 or 50 miles north of Yuma, said to be several thousand feet wide and many thousands of feet long; for this statement there was more than the usual prospector's basis, but the ore proved to be only half an inch thick.

L. H. Duschak, chemical engineer of the Bureau of Mines, reported that their station at Minneapolis has studied the use of manganese ore, and finds that steel producers are doing their best to use 30-per cent. spiegel, but the inertia of the steel workers makes the change from ferro-manganese difficult, and steel made with spiegel costs more. It is possible, but expensive, to produce high-grade ferro-manganese from low-grade ores. The establishment of a permanent manganese industry is doubtful.

Jas. M. Hyde spoke of rhodonite and rhodochrosite in the zinc lodes of Montana, where an acquaintance is trying to sort a saleable product.

T. A. Rickard considered it essential that a buying agency should be established to protect small producers.

Meeting of March 12, 1918

The meeting on March 12 was preceded by a dinner at which 26 persons were present; others attended the meeting.

It was voted to hold the June meeting in honor of the visit of the President and the Secretary of the Institute, who expect to be in San Francisco from June 16 to 20.

The paper of the evening—Recent Developments in the Metallurgy of Quicksilver—was read by Walter W. Bradley, of the California State Mining Bureau. Practically an abstract of a bulletin that is soon to be issued by the Bureau, and abounding in details of furnaces, processes, and tests, the paper does not lend itself readily to further condensation, but the book itself will be a most valuable contribution to the metallurgy of quicksilver, on which but little has been written since the publications of Professor Christy in 1885.

Investigations have been undertaken by both the California Mining Bureau and the U. S. Bureau of Mines. One of the most interesting features of the investigation was the determination of the loss in fume; this loss is much smaller than had been supposed, not exceeding 2 per cent. in proper furnaces. Up to the time of this investigation, but few determinations of quicksilver in fume had been made; technical skill and apparatus are not at the command of most operators; indeed,

most quicksilver furnaces are run without assayer or chemist. In the discussion of the paper, it was pointed out by E. A. Hersam, Professor of Metallurgy at the University of California, that the sampling of coarse quicksilver ores, such as are usually fed into the furnaces, is difficult; on account of the small content of quicksilver, large samples, not less than one or two tons, should be taken, and none of the plants is arranged for handling such samples.

The Scott furnace, invented in 1875, is the favorite and best thus far; its high installation-cost, \$1000 per ton-day, and the accumulation of quicksilver in the furnace that can be recovered only by wrecking, are drawbacks. Pyrometers used in these furnaces give better control of the operation. The extraction of quicksilver, based on the assays of feed and the residues, is about 90 per cent. At the Oceanic mine the ore assayed 0.26 to 0.36 per cent., the reject 0.02 to 0.03 per cent., an extraction of 91.7 per cent. But, taking the industry as a whole, it is not likely that more than 75 per cent. of the quicksilver in the ore is bottled. Costs of operation are from 50 to 75 c. per ton for actual running; overhead charges make the total cost from \$0.75 to \$1.25 per ton. Condensers are of many types; the circular, vertical, wooden condensers used at the New Idria mine are perhaps the best; introduction of cool moist air adds to their efficiency.

Concentration experiments show that close classification is needed before treatment on tables or belts; the ore, almost exclusively cinnabar and native quicksilver, has a specific gravity of over 8 and, in spite of the opinion of "practical" men, is readily concentrated. Senn pans do good work; flotation is not successful. Extraction of quicksilver in the wet way, by solution in alkaline sulphides, seems feasible; a plant would cost about \$500 per ton-day; probable recovery, nearly 100 per cent. It is possible that concentration and solution in alkaline sulphides may be adopted, but the process is not likely to replace the Scott furnace.

L. H. Duschak, Chemical Engineer with the U. S. Bureau of Mines, spoke briefly of the investigation which the Bureau has been making at its Berkeley experiment station on certain problems related to the metallurgy of quicksilver. The work was undertaken with the idea of accounting for the apparent discrepancies between the amount of quicksilver bottled and the theoretical production calculated from the assays of the ore and the tailing. Fume losses were determined by direct measurement at two plants using Scott furnaces, and were found to be small, not exceeding 2 per cent. of the quicksilver produced, even in the case of an ore carrying only 5 lb. per ton. Loss in the water escaping from the condenser system was also found to be very small.

The percentage of recovery now being attained by the furnace process at the best managed plants is still undetermined, but indications are that it is in the vicinity of 90 per cent. Professor Christy found a recovery of 92.7 per cent. at New Almaden in 1885.

Experiments indicate that a low red heat (600° C.) will completely expel quicksilver from small pieces of ore in about an hour's time. The prolonged heating of ore, as occurs in the Scott furnace, is therefore unnecessary. The rotary furnace under trial at New Idria has the advantage of lower installation cost, as compared with the Scott furnace; it also permits better control, and considerable variation in the time and temperature of the roasting operation, and has other advantages

which may lead to its adoption in preference to the older types of furnaces.

H. W. Gould, General Manager of the New Idria Quicksilver Manufacturing Co., gave details of the new rotary furnace (of the same type as those used in making cement) now working at his property, which seems very promising. The installation cost is but \$250 per ton-day, while automatic handling makes labor cost less than in the Scott furnace. Within six months the development of a better condensing system will probably prove the superiority of the furnace. Repairs are made with ease; no time is lost in starting and cooling the furnace, which now runs but 8 hr. daily; no absorption of quicksilver occurs in the furnace itself; and the residue contains no quicksilver. The rotary furnace is fool-proof, while in shaft furnaces improper discharging may cause important loss of quicksilver and salivation of the workmen.

C. G. Dennis described experiences with a Nevada plant; 51 per cent. of the quicksilver in the ore was bottled the first month; at the end of a year 88 per cent. was bottled. In one month, 388 per cent. of the quicksilver in the ore treated that month was bottled; this result was due to falling of the quicksilver that had been hanging on the walls of the furnace. The operation of the furnace is controlled by electric recording pyrometers.

W. H. SHOCKLEY, *Secretary*.

UTAH SECTION

WILLIAM WRAITH, *Chairman*,

CECIL FITCH, *Vice-chairman*,

F. G. MOSES, *Secretary-Treasurer*, General Engineering Co., Salt Lake City, Utah.

ERNEST GAYFORD,

E. R. ZALINSKI.

The Utah Section held a meeting at the Hotel Utah on the evening of April 4, 1918, to welcome President Sidney J. Jennings, First Vice-president Charles W. Goodale, and Secretary Bradley Stoughton, who are making visits to the different sections of the Institute. In the absence of Chairman C. W. Whitley, Water Fitch presided.

Shortly after the members had taken their places at the dinner table—still remaining standing—a service flag was dedicated and the honor roll of Utah members, containing 17 names was read. The picture of President Wilson, followed by that of Hoover, was thrown on the screen, and the National Anthem was played, the members uniting in singing. The music during the dinner included the national anthems of the Allies.

Following the dinner, Chairman Fitch introduced the speakers and read a telegram from C. W. Whitley, expressing regret at not being able to be present. President Jennings outlined the part the Institute was taking in assisting the Federal Government in various ways in war work. He also spoke of the custom established by the preceding president, Philip N. Moore, of visiting the different sections, which he was following, and thought it a good one. Secretary Stoughton gave a talk on the activities

of the Institute, and mentioned the suggestion that the name of the Institute be changed to the American Institute of Mining and Metallurgy, in order that the large membership of metallurgists might be given representation in the name. This matter was discussed by the meeting, and a standing vote was taken, showing a majority of four votes in favor of the measure. The idea did not meet with opposition, but there was a disinclination on the part of many of the members to change the long-standing name of the Institute.

Vice-president Goodale spoke on Human Engineering, on betterment of labor conditions, and the safety-first movement at Butte and Anaconda.

H. V. Winchell, who was a guest at the dinner, gave a talk on conditions in Russia, having recently spent six months in that country. The program closed with a paper by V. S. Rood and J. A. Norden on "Engineering problems encountered during the recent fire at the Utah Apex mine at Bingham." This was illustrated by lantern slides.

The meeting was an enthusiastic one, and the attendance was large, 117 members and guests having been present.

ERNEST GAYFORD, *Secretary*.

AFFILIATED STUDENT SOCIETIES

COLORADO SCHOOL OF MINES

On February 21, 1918, the students of the Colorado School of Mines who are members or have applied for membership in the Institute re-organized the "Scientific Society of The Colorado School of Mines," which has for its purpose the study and discussion of mining problems. Its meetings will be held on the first and third Wednesdays of each month, in Guggenheim Hall.

Following are the officers:

R. W. GIBSON, *President*,
W. A. CONLEY, *Vice-president*,
F. L. SERVISS, *Sec'y.-Treas.*

At present there are 62 members, seven of whom are Faculty members.
F. L. SERVISS, *Secretary*.

EMPLOYEES' WELFARE

Readers of recent *Bulletins* have doubtless observed that the problem of improving both material and moral condition of employees is receiving close attention from influential members of the Institute. This will lend interest to certain developments and investigations that have been reported elsewhere.

COST AND OUTCOME OF BETTERMENT ACTIVITIES

A recent Federal investigation into the expense incurred by employers in carrying out their plans for improving the condition of their workmen is reported in the March *Monthly Review* of the U. S. Dept. of Labor, p. 691, as follows:

It was found in this particular phase of the welfare study that it was difficult to get very exact information, both on the costs and on the comparison of the present conditions with those prevailing before service work for the employees began. It was rather surprising to find that few firms had definite knowledge of what the work was costing them. In the majority of cases, even with a fairly well-organized department, no separate record of the expenditures was kept, and in those establishments which were able to give the amounts expended, there was so much diversity in the forms of welfare work for which the figures were given that it is difficult to make a comparison or arrive at very definite conclusions as to the outlay which might be considered to be a reasonable one. The costs, as given, vary from a fraction of 1 per cent. to 5 per cent. of the total annual pay roll. In those cases where the allowance is as high as 4 and 5 per cent., the costs of the pension or group insurance plans and the contribution to the benefit associations or the maintenance of an expensive club-house form a large part of the expense. It seemed, taking into consideration the scope of the work in relation to the costs, as reported by the different companies, that, excluding unusual contributions to these features, a fairly comprehensive program could be maintained for about 2 per cent. of the annual pay roll. Another element to be taken into consideration in this matter of costs is the degree of participation of the employees. Those examples of welfare which cost the firms the most are not necessarily the most successful, since advantages are appreciated by most people in measure as they give to them, both of money and effort. A company which, while encouraging and aiding such work, still leaves a share in both the management and the expense to the employee is probably nearer to harmonious plant relations than the employer who gives lavishly but administers the work in a more or less paternalistic spirit.

Comparison of Present Conditions with Those Prevailing Before Welfare Work Began

In spite of the fact that so much of this work is comparatively recent, it will readily be seen that, owing to the abnormal labor conditions of the past three years, it was very difficult to obtain from the companies a comparison of present conditions with those prevailing before welfare work was undertaken. The extent to which the output is affected by the welfare work is difficult to determine, both because of the present unusual labor conditions and the fact that few companies had made any study of this point. A few firms, however, gave it as their opinion that the output had been increased by it, although several of these stated that this improvement was only in part due to the welfare work. Quite a number stated that their increased output was due to a reduction in the working hours, a form of welfare which has not been given special consideration in this report.

The stability of the force also has been much affected in many plants by present labor conditions. Of the establishments scheduled, 136 reported an improvement in this regard, due in whole or in part to the betterment activities. In many cases this was more than a mere expression of opinion, since many employers have, of late, been impressed with the fact that a large turnover is a very important item in the cost of production, and have been seeking to reduce this turnover by more scientific management of the employment departments and by the introduction of welfare features. One firm which had compiled statistics in regard to the reduction in the turnover had an increase of 13.4 per cent. of employees of more than two years' service, in 1916, over a similar group for 1914, due entirely, so the management stated, to their welfare work.

Of the establishments interviewed, 160 reported an improvement in the time lost. There are probably two reasons for this: One is the work of the emergency hospitals, which care for the general health of the employees and do much preventive work, as well as sort out those most undesirable physically through their examinations on entrance; the other is the installation of safety devices and the education through safety lectures and literature, which has resulted in a large reduction in the time lost through industrial accidents.

THE HOUSING PROBLEM

The problem of providing suitable living accommodations for its employees has always demanded, and has frequently received, earnest consideration from the larger mining companies. Recent emergency conditions in the manufacturing industries, however, have brought this problem emphatically into the foreground. The manner in which the problem has been solved at Bridgeport, Conn., which about two years ago began a phenomenal period of growth in munitions manufacturing, has been described by W. E. Freeland, in *The Iron Age*, for March 21, 1918.

The Chamber of Commerce initiated the organization of the Bridgeport Housing Co., with a capital of \$1,000,000, which was subscribed by 20 industrial concerns of the city, the stockholders voluntarily limiting their dividends to 6 per cent. Three large plots were then purchased, architects, sanitary engineers and landscape gardeners were put to work, and construction was begun. The first structure to be finished was an apartment house.

This house has 39 apartments of three rooms and bath each. A similar type of house is frequently found in New York under the name of studio apartments. The building has a roof garden and every apartment opens onto a fire escape arranged to serve as a veranda. The building is situated within five minutes' walk of a bathing beach at one of the city parks. The three upper floors are rented at \$30 for each apartment and the lower floor at \$25. This includes heat and hot water, but each tenant pays for lights. This apartment house has appealed to the clerical workers of the city for whose needs it was particularly designed. Like all the other homes built by the company, it is equipped with all the appliances that are considered a part of a modern city home, such as gas ranges, kitchen cabinets, shades, screens, etc. Building during a period of high costs, this structure pays a fair return on the investment, which was \$2410 for each family, plus \$154 for land and development, including sidewalks, hedges and other planting. (Additional data as to erection of group and detached houses will be found in the paper cited—Ed.)

The Manufacturer's Part in Solving the Housing Problem

The manufacturers' interest in the problem lies in its effect upon his labor turnover. A considerable part of this turnover now is due to unsatisfactory home conditions, the uneconomical living in a house too large or in a portion of a house too small for full equipment. Pride in home has almost dropped out of city life, but it is an important part of the social life of the country today, and in the Americanization of foreign workers and the stabilization of factory labor. The city which builds the most attractively and furnishes the most economical home will reflect in the factory the greatest reduction in labor turnover. It is distinctly a manufacturers' problem.

Financing the Permanent Dwelling

The people must pay for the houses that are to solve the home problem of industrial workers—but the workers cannot pay all cash. The investing class must enter into the problem with its funds for a time. The wage earner can pay, over a long period of years, proper charges for the proper house. Otherwise his wage is wrong and should be corrected. We have taught the worker to invest in national bonds. If we can teach the worker to continue to keep on buying bonds, we can help him to own his home. It becomes the manifest duty of the employer to underwrite these bonds and to guarantee their security. The duty and the responsibility of the employer can be expressed in three simple statements:

1. The capitalists who now have the money of the country in their own hands can dictate whether the class of home owners shall be enlarged or not, unless manu-

factor and laborer cooperate to establish a new order of things which will eliminate landlordism.

2. We are in changing period of history in this country and citizenship is a supreme demand of the future.

3. It is unfair to the man who has been taught to buy Government bonds to offer him a share in anything that is not safe and liquid.

LOW-COST HOUSING IN AMERICA

How to meet, at low cost, the requirements of housing which shall be adequate in point of shelter, sanitation, provision for family life, and esthetic pleasure is the subject of a pamphlet recently issued from the Department of Social Ethics of Harvard University.* It describes plans of one-family and semi-detached houses actually constructed for approximately \$2000 per dwelling. It is confined largely to examples of work done by employers, the data having been secured by correspondence with the companies. The following recapitulation of the contents of this pamphlet is extracted from the March *Monthly Review* of the U. S. Department of Labor, p. 697.

The study emphasizes that the suggestions presented in regard to comparative costs of the houses of different types and materials are to be considered as "merely suggestive, and are not entitled to carry the weight of authority." Among the conclusions arrived at are: That shingled houses are more expensive than clapboards; brick about 7 per cent. more expensive than frame (clapboarded), and stucco on metal lath about 3 per cent. more expensive than frame. Data on concrete are too scant to make any estimate.

Frame construction seems likely to decrease because of the generally increasing cost of lumber as compared with that of clay and cement products, and because of the fire risk and high maintenance cost of frame houses. But in many localities wood still remains cheaper than other building material. It will also tend to be used wherever social changes are occurring so rapidly that a more permanent type of dwelling would be an unprofitable investment. Brick is to be recommended wherever local conditions are such that it can be cheaply secured. Hollow tile is in somewhat the same class, though requiring further development before its possibilities can be fairly judged. Concrete, especially "poured" concrete, is of value chiefly in large-scale housing undertakings, though of course the steel forms once bought can be used to pour one house or a hundred. The progress of stucco depends especially on the certitude of good workmanship in its use.

MEMBERS OF THE INSTITUTE IN MILITARY SERVICE

(The following list contains the names of those members of the Institute of whose connection with military service we have only recently become acquainted; it also includes the names of a few who have recently been promoted or transferred. A complete list was published in the Year Book, issued as a supplement of the *Bulletin* for March, 1918.)

ADAMS, HENRY, Major, Assistant to Department Engineer, North-eastern Dept.

ALINE, P. A., Co. C, 316th Supply Trains.

* Low-cost cottage construction in America; a study based on the housing collection in the Harvard Social Museum, by Winthrop A. Hamlin. Cambridge, Mass., Harvard University, 1917. (Publications of the Department of Social Ethics, No. 7.) 30 pp., 4 charts. Illus.

- ALLEN, ROY HUTCHINS, 1st Lieutenant.
ANDERSON, BARCLAY G., Co. B, 318th Engineers.
ARCHBALD, HUGH, Captain, Infantry, National Army.
BEDDALL, THOMAS H., 1st Lieutenant, Co. B, 1st Battalion, 30th Engineers, A. E. F.
BELL, L. R., Co. I, 308th Infantry.
BELLIS, ARTHUR E., Ordnance Reserve Corps.
BILLICK, DON C., Ordnance Dept., U. S. Army.
BOOTH, L. E., Co. R, Ordnance Training Camp.
BRUNS, C. L., JR., School of Military Aeronautics, Mass. Inst. of Tech.
CALDER, NORMAN L., Sapper No. 320370, I. W. & D., Royal Engineers.
CAMPBELL, WILLIAM, Met., New York Navy Yard.
COLLINS, F. A., Lieutenant, U. S. N. R. F., Naval Aviation Forces, A. E. F.
COMINS, W. H., Captain, 41st Co., 164th Depot Brigade.
COONER, JOHN D., Co. A, 30th Engineers, A. E. F.
CORTESE, EMILIO, Volunteer, Italian Army.
CRAMPTON, FRANK A., Corporal, Co. C, 115th Engineers.
DAVID, JOSEPH, 2d Lieutenant, Office of Chief of Engineers, Washington, D. C.
DOBSON, D. I., Co. F, 310th Engineers.
ELLIOT, STUART R., Major, 28th Engineers, A. E. F.
ERDOFY, MAXWELL E., 2d Lieutenant, Headquarters Co., 602d Engineers.
FERRIS, A. L., Engineer Reserve Officers' Training Camp.
FRASER, THOMAS, Aviation Section, Reserve Officers' Training Camp.
FRENCH, L. H., Lieutenant-Commander, U. S. N. R. F., Army and Navy Club, Washington, D. C.
GRAHAM, ERNEST R., Captain, 309th Engineers.
GRAHAM, W. F., 2d Lieutenant, Ordnance Reserve Corps.
GRANT, ULYSSES S., 2d Lieutenant, Equipment Section, Procurement Division, Army Ordnance Dept.
GUGGENHEIM, HARRY FRANK, Lieutenant, U. S. N. R. F., Naval Aviation Forces, A. E. F.
HARTLEY, BURTON, 1st Lieutenant, Coast Artillery Reserve Corps.
HENDERSON, GEORGE M., 1st Lieutenant, Engineer Officers' Reserve Corps.
HENRY, WILBUR E., 1st Lieutenant, Ordnance Reserve Corps.
HOLMES, JOSEPH A., 2d Lieutenant, Battery E, 151st Field Artillery, A. E. F.
HOOKER, WALTER, Lieutenant, R. E., 272d Railway Co., Egyptian Field Force, Egypt.
HUBER, J. E., Co. B, 14th M. G. Battalion, 9th Brigade, 5th Division.
IONIDES, S. A., Explosives Department, Imperial Munitions Board, Ottawa, Ont., Canada.
JARDINE, F. M., 1st Lieutenant, 12th Regiment.
JOHNSTON, FRED L., Captain, 434th Engineers.
KEENAN, EDWARD T., Captain, Engineers, U. S. R., 37th Co.
KINNEY, H. D., 1st Lieutenant, 27th Engineers.
KREBS, JOSEPH J., Battery A, 18th Field Artillery, A. E. F.
LANAGAN, WILLIAM H., Major, Engineer Reserve Corps, U. S. A.
LANDERS, WILL H., Captain, 27th Engineers, A. E. F.
LEAVELL, JOHN H., Captain, Co. F, 316th Engineers.

LINDHOLM, MILTON S. Sergeant, Headquarters Co., 340th Field Artillery, N. A.

McCLELLAND, JAMES F., Aircraft Board.

McINTOSH, F. K., 1st Lieutenant, Co. C, 28th Engineers.

MACDOWELL, Charles H., Chemical and Explosive Section, War Industries Board, Council of National Defense.

MACKENZIE, JOHN D., Lieutenant, 185th Cape Breton Highlanders, C. E. F.

MARQUARDT, ERNEST, 2d Lieutenant, 602d Engineers.

MARSH, ROBERT, JR., Captain, Aviation Section, A. E. F., France.

MEANS, A. H., Headquarters Co., 304th Field Artillery, N. A., 77th Division.

MEGRAW, H. A., Production Engineering Department, U. S. Army, Signal Corps.

MICKEL, R. E., 2d Lieutenant, Engineer Officers' Reserve Corps, L. of C., A. E. F.

MORRIS, N. M., Sergeant, Supply Co., 333d Infantry.

ORD, JAMES, Corporal, detached service, Care Weather Bureau, Philadelphia, Pa.

PEACOCK, D. C., Captain, 311th Engineers.

PHILLIPS, D. McN., 1st Lieutenant, Signal Reserve Corps, Aviation Section.

POND, WILLIAM F., 1st Lieutenant, Engineering Corps.

PORCH, E. L., JR., Aviation School.

POWERS, SIDNEY, 2d Lieutenant, U. S. Geological Section, Engineering Section.

PULLEN, ERNEST F., Canadian Army, C. E. F., France.

RAMAGE, ALFRED HULL, Aviation Section, U. S. Signal Corps.

READ, T. T., Requirements Section, Control Bureau, Ordnance Dept.

RICKARD, HAROLD, Lieutenant, Royal Engineers, B. E. F.

ROBERTS, MORGAN E., Barracks No. 7, Engineer Officers' Training Camp.

RODGERS, ALAN M., Lieutenant, 312th Engineers.

ROPER, GEORGE, JR., Lieutenant, Royal Flying Corps.

ROYCE, WARD, Captain, Co. B, 27th Engineers.

SANFORD, H. E., Co. C, 4th Engineers.

SCOTT, H. KILBURN, Director, Home Ore Supplies, Gold Street Chambers, Kettering, Northamptonshire, England.

SCOTT, W. M. HENDERSON, Headquarters, Mediterranean Lines of Communication, A. P. O.

SPURR, J. EDWARD, U. S. Shipping Board.

STEIDLE, EDWARD, 1st Lieutenant, Co. A, 30th Engineers, A. E. F.

STEWART, LEIGHTON, Lieutenant, Canadian Engineers, Engineers' Training Depot, St. John's, Quebec, Canada.

STONE, FRANK M., Q. M. C. N. A., M. R. S. No. 303, A. P. O. No. 708, A. E. F., France.

STRINGHAM, JOSEPH S., Captain, Engineer Officers' Reserve Corps, U. S. Arsenal.

SULLIVAN, CLARKE, Captain, Engineer Officers' Reserve Corps.

SULLY, KENNETH M., Corporal, Co. C, 29th Engineers.

TARANTOUS, RICHARD, Lieutenant, 8th Mountain Engineers.

TAYLOR, HENRY B., 2d Lieutenant, Signal Reserve Corps, Aviation Section.

THOMPSON, LESTER S., Co. C, 29th Engineers.

THOMSON, S. C., War Export Board.

TICHBORNE, HERBERT M., 88th Aviation Section, Signal Corps,
A. E. F.

TITZELL, GEORGE G., JR., Flying Cadet, 5th Squadron Aviation.

VAIL, RICHARD H., Requirements Section, Control Bureau, Ordnance
Department, Washington, D. C.

WATKINS, JOSEPH C., Major, 2d Battalion, Second Engineer Training
Regiment.

WEARNE, WILLIAM, Captain, Engineer Officers' Reserve Corps.

WEBB, CURTIS C., Reserve Officers' Training Camp.

WHITTINGHAM, HAROLD, Major, 71st Heavy Battery, R. G. A.

WRAY, DAVID C., Local Exemption Board, Division 2, Bureau Co., Ill.

YOUNG, FRED W., A. E. F., France.

ZIESEMER, HARRY M., American Red Cross.

ZIMMERMAN, S. H., 1st Battalion, 107th Engineers, A. E. F.

PERSONAL

The following is an incomplete list of members and guests who called at Institute headquarters during the period Mar. 10, 1918 to Apr. 10, 1918.

W. Sinclair Brown , Lebong Donok, Sumatra.	F. Laroque , Roodepoort, Transvaal.
H. B. Catlin , Syracuse, N. Y.	A. H. Means , Camp Upton.
A. R. Chambers , New Glasgow, Nova Scotia.	J. H. Miles , Nome, Alaska.
W. M. Corse , Buffalo, N. Y.	Harvey S. Mudd , Washington, D. C.
George C. Crossley , Toms River, N. J.	Henry Noyes , Melbourne, Aust.
F. A. Dalburg , Montoursville, Pa.	C. L. Petzel , Camp Upton.
Kuno Doerr , El Paso, Tex.	J. L. Schueler , Peoria, Ill.
V. E. Edwards , Worcester, Mass.	J. G. Scrugham , Reno, Nev.
H. F. E. Gamm , Rutherford, N. J.	Frank M. Smith , East Helena, Mont.
J. W. Gerhard , St. Louis, Mo.	W. G. Swart , Duluth, Minn.
Julius H. Gillis , Sudbury, Ont., Canada.	A. L. Sweetser , Boston, Mass.
S. J. Gormly , Guayacan, Chile.	W. N. Thayer , Cincinnati, Ohio.
Fletcher Hamilton , San Francisco, Cal.	Felix E. Wormser , Cornucopia, Ore.
Dorsey A. Lyon , Washington, D. C.	

John B. Arnold has opened offices at 606 Lyceum Bldg., Duluth, Minn.

E. E. Barker, formerly mine superintendent with the Chile Exploration Company at Chuquicamata, Chile, has resigned his position to become superintendent of mines for the Cerro de Pasco Copper Corporation at Cerro de Pasco, Peru.

H. Smith Clark has accepted a position with the Scoville Manufacturing Co., Waterbury, Conn.

Will L. Clark has resigned as Fuel Administrator for Arizona.

Herbert B. Cox has resigned his position with the Emergency Fleet Corporation and is now with the Ringwood Company, 50 Church Street, New York, N. Y.

Robert E. Dye is now superintendent, Teck-Hughes Gold Mines, Ltd., Kirkland Lake, Ont., Canada.

William G. Eberhardt has accepted a position with the Cia. Oriental de Minas, San Basilio Baja 3, Santiago, Cuba.

R. C. Eisenhauer is now resident engineer, Montana Cons. Copper Co., Basin, Mont.

James R. Finlay has removed his office from 52 William St. to 45 Cedar St., New York, N. Y.

Emil A. Franke has accepted a position with the Cerro de Pasco Copper Corporation, Casilla 309, Lima, Peru.

Edward H. Hamilton has accepted a position with the U. S. Smelting Co., Midvale, Salt Lake City, Utah.

E. C. Harder is now with the U. S. Geological Survey, Washington, D. C.

Alfonse H. Heller has accepted a position as superintendent of the Afterthought Copper Co., Ingot, Cal.

Jesse V. Howell is now geologist with the Gypsy Oil Co., Wichita Falls, Kans.

Fred Lucian Johnston is now mechanical engineer with E. I. DuPont de Nemours and Co., U. S. Nashville Smokeless Powder Plant, Nashville, Tenn.

James T. Kemp is now employed at the works of The International Nickel Co., of Canada, Ltd., Port Colborne, Ontario.

Robert L. Martin, Jr., is efficiency engineer, Northampton coke plant, Bethlehem Steel Co., Northampton, Pa.

W. G. Matteson has resigned his position with the Texas Company and has opened offices in Fort Worth, Texas, as consulting petroleum geologist and engineer.

Arvid E. Nissen has resigned his position with the American Graphite Co. of Chicago, and accepted a position on the metallurgical staff of the Taylor-Wharton Iron & Steel Co., High Bridge, N. J.

Holman I. Pearl has accepted a position with the Mines Efficiency Co., 709 Alworth Bldg., Duluth, Minn.

Curtis Pigott has severed his connection with the U. S. Smelting Co., of Midvale, Utah, and has accepted a position with the St. Joseph Lead Co., Herculaneum, Mo.

Richard G. Place is now chemist, Ray Cons. Copper Co., Box 734, Hayden, Ariz.

Jasper T. Robertson has accepted a position with the Afterthought Copper Co., Ingot, Cal.

Guy H. Ruggles is now with the Inspiration Cons. Copper Co., Miami, Ariz.

J. E. Rypinski has accepted a position with the Utah Metal & Tunnel Co., Bingham Canyon, Utah.

L. Salazar S. has recently been appointed Head of the Department of Explorations and Geological Studies of the Mexican Government, with headquarters in the building of the Instituto Geologico de Mexico.

Robert H. Seip has accepted a position as engineer with Witherbee Sherman & Co., Inc., Mineville, N. Y.

Charles M. Shannon has been appointed Fuel Administrator for Arizona.

Lloyd A. Womble is now connected with the Union Minière du Haut Katanga, Elisabethville, Congo Belge, South Africa.

Harold W. Yost is now asst. efficiency engineer, Phelps-Dodge Corp., Burro Mountain Branch, Tyrone, N. M.

POSITIONS VACANT

Draftsman and transitman for coal mine work in Middle West. Salary \$125 per month. No. 277.

Technical graduate wanted for metallurgical work in experimental laboratory of large New England manufacturing concern. A knowledge of metallography of steel is essential. Practical experience is desirable but not required. No. 305.

High-class man to install and take charge of a coal mining property. Must be experienced in handling labor and of good sound judgment. Work will require a man to be on the grounds practically all the time. The work is drift mining and is not gaseous. No. 306.

Engineer familiar with the acid treatment and melting of cyanide precipitates; also a competent assayer. Applicant must be able to furnish good references. No. 307.

Wanted—practical mining man, foreman, or superintendent for work in middle or southern Atlantic States. Salary \$200 per month. No. 308.

ENGINEERS AVAILABLE

(Under this heading will be published notes sent to the Secretary of the Institute by members or other persons introduced by members.)

Member, graduate Columbia School of Mines, age 35, married, best of health, dependable, desires position as manager or scout for reliable interests. Experience covers responsible positions incident to the mining and milling of gold-silver, copper, lead, and zinc ores, and the examination of base and rare-metal deposits in United States and Mexico. Salary \$3600. Available April 1. No. 453.

Member, mining engineer, technical training, age 32, assayer, engineer and superintendent of porphyry copper development, churn drilling and shaft sinking. Examination of prospects and development of gold prospects. Considerable flotation experience. No. 454.

Young Columbia graduate, conscientious worker, with experience in inorganic analysis, surveying, draughting, and with post-graduate training in geology, desires position with prospects. Minimum salary considered, \$130 in U. S. and \$150 in Mexico. At present employed. Draft exempt. No. 455.

Member, who has had experience for the past fifteen years in gold and silver mining and metallurgy, wishes to be placed in communication with a reliable company desiring the services of a general manager or general superintendent. At present employed, but will be open for engagement May 1. No. 456.

Mining engineer and geologist desires a position as manager, superintendent, or examining engineer with a sound, responsible concern; member, technical graduate, and 12 years' experience covering all branches of metal mining. Good executive, and specially qualified in examination work and development of properties. No. 457.

FORTHCOMING MEETINGS OF SOCIETIES

Organisation	Place	Date 1918
American Iron and Steel Institute	New York, N. Y.	May
American Water Works Association	St. Paul, Minn.	May 20-25
American Institute of Chemical Engineers	Berlin, N. H.	June 19-22
American Concrete Institute	Atlantic City, N. J.	June 24-26
American Society for Testing Materials	Atlantic City, N. J.	June 25-28
New York Electrical Society	New York, N. Y.	June
National Association of Stationary Engineers	Cincinnati, O.	Sept. 9-13
National Exposition of Chemical Industries	New York, N. Y.	Sept. 23-28
American Chemical Society	Cleveland, O.	Sept.
National Petroleum Association	Atlantic City, N. J.	Sept.

DIAMOND MINES OF SOUTH AFRICA

The Institute still has in stock a few copies of Dr. Gardner F. Williams' magnificent book on "The Diamond Mines of South Africa," which he is selling through the Institute for the benefit of the Red Cross. The two volumes, beautifully illustrated, very handsomely bound in full levant, sell for \$10; in $\frac{3}{4}$ leather, \$8; and in cloth binding, \$5. The Institute makes no charge for handling this book and the entire receipts are devoted to the Red Cross, in the case of the levant and $\frac{3}{4}$ leather volumes. In the case of the cloth-bound books, the cost of binding has to be paid, but all the remainder is handed to the Red Cross.

LIBRARY

AMERICAN SOCIETY OF CIVIL ENGINEERS

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

AMERICAN SOCIETY OF MECHANICAL ENGINEERS

AMERICAN INSTITUTE OF MINING ENGINEERS

UNITED ENGINEERING SOCIETY

HARRISON W. CRAVER, Director

The Library of the above-named Societies is open from 9 A. M. to 10 P. M. except on holidays. It contains about 70,000 volumes and 90,000 pamphlets, including sets of technical periodicals and publications of scientific and technical societies

Members of the Institute, with few exceptions, are forced to spend a portion of their time in localities isolated from sources of information. To these the Library, through its Library Service Bureau, can render valuable service through correspondence; letters requesting information will receive especial attention. The Library is prepared to furnish references and photographic copies of articles on mining and metallurgical subjects; to determine the existence of mining maps, and to furnish general information on the geology and mineral resources of all countries.

All communications should be made as definite as possible so that the information received may be what is desired and not include collateral matter which may not be of interest. The time spent in searching for such collateral matter will be saved, and the information will be sent more promptly and in more usable shape.

Library Accessions

INCOMPLETE LIST CLASSIFIED BY SUBJECTS

Mining and Metallurgy

AMERICAN COALS FOR EXPORT. An economic inquiry into the ability of American coals to compete, should they seek world markets. By Ernest M. Merrill. Beckley, 1917.

FOAMING OF BOILER WATERS. (South Australia, Dept. of Chemistry. Bulletin No. 5.) Adelaide, 1917.

ADVANTAGES OF MODERN TYPES OF DIRECT-CURRENT MACHINES. By David Hall. A paper presented at the 10th Annual Convention of the Association of Iron and Steel Electrical Engineers, Sept. 18-22, 1916. East Pittsburgh, Pa.

DIGEST OF PUBLICATIONS OF BUREAU OF STANDARDS ON ELECTROLYSIS OF UNDERGROUND STRUCTURES CAUSED BY THE DISINTEGRATING ACTION OF STRAY ELECTRIC CURRENTS FROM ELECTRIC RAILWAYS. By Samuel S. Wyer. Columbus, 1918.

HYDRAULIC TURBINES. I. P. Morris Co., Hydraulic Dept. Bulletin No. 4. Philadelphia. The William Cramp & Sons Ship & Engine Building Co., 1915.

SOME ELECTRICAL PROBLEMS PRACTICALLY CONSIDERED. By B. G. Lamme. A paper presented at the 8th Annual Convention of the Association of Iron & Steel Electrical Engineers, Sept. 14-19, 1914.

FORGES AND FURNACES IN THE PROVINCE OF PENNSYLVANIA. Prepared by The Committee on Historical Research. Philadelphia, 1914. (Gift of American Institute of Mining Engineers.)

- GREAT BRITAIN. Department of Scientific and Industrial Research Advisory Council. Report on the sources and production of iron and other metalliferous ores used in the iron and steel industry. London, 1918.
- HEAT TREATMENT OF HIGH-SPEED STEEL. By Garnet W. McKee. Ed. 3.
- HEAT TREATMENT OF STEEL IN GAS FURNACES. By Garnet W. McKee. Ed. 4. Rockford, Ill., 1918.
- L'INDUSTRIE DE L'ACIER EN FRANCE. By J. Tribot-Laspière. Paris, 1916.
- STRUCTURAL STEEL FOR SHIPS. Standard practice recommended by American steel makers as adopted by the Emergency Fleet Corporation. Pittsburgh, Pa., 1917.
- MEMORANDUM RESPECTING THE QUALITY OF SPELTER SUITABLE FOR THE MANUFACTURE OF CARTRIDGE BRASS AND OTHER HIGH-GRADE BRASS. By W. R. Ingalls. New York, 1917.
- U. S. ORDNANCE DEPARTMENT. Report of the Test of Metals and other Materials, 1915, 1916. Washington, 1917.

Geology and Mineral Resources

- BOLIVIA. Official information and statistics, summarized by Julio Zamora. New York.
- HAWAII. Its natural resources and opportunities for home-making. By F. H. Newell. Washington, 1909.
- IDAHO. Mining Industry. Annual Report, 1917. Boise, 1918.
- IOWA. Geological Survey. Annual Report, 1915. Des Moines, 1917.
- SOUTH DAKOTA. State Inspector of Mines. Annual Report. Lead, S. D., 1915-16.
- WESTERN AUSTRALIA. Annual Progress Report of the Geological Survey, in 1916. Perth, 1917.
- GEOLOGY AND ORE DEPOSITS OF MEEKATHARRA, MURCHISON GOLDFIELD. With maps and sections. Western Australia Geological Survey, Bulletin No. 68. Perth, 1916.
- CONTRIBUTIONS TO THE STUDY OF THE GEOLOGY AND ORE DEPOSITS OF KALGOORLIE, EAST COOLGARDIE GOLDFIELD, PART III. With maps and sections. Western Australia Geological Survey, Bulletin No. 69. Perth, 1916. (Purchase.)

Book Notices

Unless otherwise specified, books in this list have been presented by the publishers. The Institute does not assume responsibility for any statements made; these are taken from the preface or the text of the book.

CHEMICAL PATENTS; AND ALLIED PATENT PROBLEMS. By Edward Thomas. Washington, John Byrne & Co., 1917. 58 pp., 9 × 6 in., cloth, \$2.50.

This work is intended to provide a statement of the law of the chemical patents, together with a practically complete list of the cases on which it is based, and of the principal cases intimately related in reasoning to them. Written from the point of view of the patent attorney and the expert witness.

AIDS IN THE COMMERCIAL ANALYSIS OF OILS, FATS, AND THEIR COMMERCIAL PRODUCTS; a Laboratory Handbook. By George Fenwick Pickering. Phila., J. B. Lippincott Co.; Lond., Charles Griffin and Co., 1917. 133 pp., 9 × 6 in., cloth.

Intended as a guide in works laboratories. The tests for determining the purity of the substances and their suitability for various purposes are given, together with tables of constants for each. These values, the author states, are here published for the first time.

A SHORT HAND-BOOK OF OIL ANALYSIS. By Augustus H. Gill, 8th ed. rev. Phila. and Lond., J. B. Lippincott Co. (copyright 1918) 209 pp., 9 illus., 8 × 5 in., cloth.

This well known manual is designed to provide a concise account of the methods of applying the usual physical and chemical tests to oils. The eighth edition has been revised, descriptions of some new forms of apparatus included and some minor tests and new methods added.

THE CALORIFIC POWER OF FUELS; with a Collection of Auxiliary Tables and Tables Showing the Heat of Combustion of Fuels, Solid, Liquid and Gaseous. By Herman Poole. 3d ed. rewritten by Robert Thurston Kent. N. Y., John Wiley &

Sons, Inc.; Lond., Chapman & Hall, Ltd., 1918. 10 + 267 pp., 65 illus., 9 × 6 in., cloth, \$3.

The introduction of new fuels, the improvements in the methods of investigating the calorific power of fuels and the increase in the amount of available accurate data have made it necessary to rewrite the book. The latest researches have been incorporated, inaccurate data occurring in earlier editions has been eliminated and the results have generally been reported in the English system of units instead of in the metric system used in former editions.

THE GAS ENGINE HANDBOOK. A Manual of Useful Information for the Designer and the Engineer. By E. W. Roberts. 9th ed. rewritten and enl. Cincinnati, The Gas Engine Publishing Co. (copyright; 1917) 315 pp., 80 illus., 7 × 5 in., leather, \$2.

An epitome of gas engine practice, in pocket book form, intended as a handy book of reference. This ninth edition has been revised to show present practice. Contents: Descriptive; Design; Operation; Testing; Selection.

GAS, GASOLINE AND OIL ENGINES. A complete, practical work defining clearly the elements of internal-combustion engineering. Treating exhaustively on the design, construction and practical application of all forms of gas, gasoline, kerosene and crude petroleum-oil engines. Describes minutely all auxiliary systems, such as lubrication, carburetion and ignition. Considers the theory and management of all forms of explosive motors for stationary and marine work, automobiles, aeroplanes and motorcycles. Includes also producer gas and its production. By Gardner D. Hiscox, rev., enl. and brought up to date by Victor W. Pagé. 22d ed. N. Y., The Norman W. Henley Publishing Co., 1918. 640 pp., 435 illus., 9 × 6 in., cloth, \$2.50.

The present edition of this well known work has been very thoroughly revised throughout, and an attempt has been made to include all recent developments of importance. New tables, formulas and illustrations have been included and obsolete material has been eliminated, except when of historical interest.

THE PETROLEUM AND NATURAL GAS REGISTER. A Directory of the Petroleum and Natural Gas Industries in the United States, Canada and Mexico, 1917-1918 ed. N. Y., The Oil Trade Journal. 548 pp., 12 × 9 in., cloth, \$10.

Includes in one directory material on all branches of the petroleum and natural gas industry. The work is based on statements made by officials of the companies listed, and gives the usually needed information as to properties, capital stock, officers, etc.

BROWN'S DIRECTORY OF AMERICAN GAS COMPANIES, 1917. Compiled and Corrected Annually by E. C. Brown. N. Y., The Gas Age, 1917. 897 pp., 11 × 7 in., cloth, \$5.

This edition summarizes the statistics of 1179 manufactured, 768 natural, 134 acetylene and 70 gasoline gas companies, 161 parent or operating companies and 47 public service commissions. An appendix includes the financial data of 277 companies, the officers, directors and committees of gas associations and an alphabetical list of gas association members, with their company and association affiliations.

A SUPPLEMENTARY MEMOIR ON BRITISH RESOURCES OF SANDS AND ROCKS USED IN GLASS-MANUFACTURE; with Notes on Certain Refractory Materials. By P. G. H. Boswell with Contributions by W. B. Wright, H. F. Harwood and A. A. Eldridge. N. Y. and Lond., Longmans, Green and Co., 1917. 85 pp., 7 pl., 8 × 6 in., paper, \$1.

Supplements the memoir of the same title which was published in 1916. Describes further supplies and treatment of materials, so that the study of British resources of glass-sand is now believed to be fairly exhaustive. A chapter on American high-grade sands is included.

TECHNICAL MECHANICS; Statics and Dynamics. By Edward R. Maurer. 4th ed. rev. and enl. N. Y., John Wiley & Sons, Inc.; Lond., Chapman & Hall, Ltd., 1917. 381 pp., 178 illus., 9 × 6 in., cloth, \$2.50.

A theoretical mechanics written for students of engineering, in which each subject discussed has a direct bearing on some engineering problem. The book thus differs from those commonly called theoretical mechanics, which are generally intended for students of mathematics or physics. It is, on the other hand dissimilar to books commonly entitled applied mechanics.

The fourth edition differs from the third by the addition of 176 more problems and

the modification of the articles on axle reactions, efficiency of machines, hoists, gyrostats, kinetics of plane motion, rolling resistance, kinetics of a body with a fixed point, and the dynamics of any motion of a rigid body.

THE ELEMENTS OF RAILROAD ENGINEERING. By William G. Raymond. 3d ed. rev. N. Y., John Wiley & Sons, Inc.; Lond., Chapman & Hall, Ltd., 1917. 24 + 453 pp., 107 illus., 9 × 6 in., cloth, \$4.

This book attempts to describe the fixed portion of a railroad plant and to give the underlying principles of the design of its layout. The present edition has been largely revised and the introduction has been modified to conform to the progress that has been made in the study of valuation and regulation of utilities, the discussion of engine capacity and the chapters on signalling have been rewritten, and a chapter on the principles of valuation has been added. Contents: Introduction; Permanent Way; The Locomotive and its Work; Railroad Location, Construction and Betterment Surveys; Appendix.

OXY-ACETYLENE WELDING PRACTICE. A practical presentation of the modern processes of welding, cutting, and lead burning, with special attention to welding technique for steel, cast iron, aluminum, copper, and brass. By Robert J. Kehl. Chic., American Technical Society, 1918. 102 pp., 111 illus., 8 × 5 in., cloth, \$1.

A well illustrated description of the methods and appliances in use, intended for the workman and superintendent. Contents: Welding Processes; Technique of Oxy-acetylene Welding; Miscellaneous Oxy-acetylene Processes; Examples of Automobile Repair; Costs.

A BIBLIOGRAPHY OF THE WAR CRIPPLE. Compiled by Douglas C. McMurtrie.

THE ECONOMIC CONSEQUENCES OF PHYSICAL DISABILITY. A Case Study of Civilian Cripples in New York City. By John Culbert Faries.

MEMORANDUM ON PROVISION FOR DISABLED SOLDIERS IN NEW ZEALAND. By Douglas C. McMurtrie. N. Y. Red Cross Institute, 1918. 11 × 8 in., paper.

These pamphlets form the first three numbers of the Publications of the Red Cross Institute for Crippled and Disabled Men, a series edited by Mr. McMurtrie. The bibliography covers 39 pages and will be further extended by supplements as new material accumulates.

MECHANICAL EQUIPMENT OF SCHOOL BUILDINGS. By Harold Alt. Milwaukee, The Bruce Publishing Co. (copyright 1916) 111 pp., 160 illus., 11 × 8 in., cloth, \$2.50.

A discussion of the various problems which arise in the design and installation of the equipment for ventilating, heating, lighting, sewage disposal, cleaning, toilets, drinking water, fire protection, etc., by an engineer with experience as a designing and supervising engineer.

PRACTICAL SANITATION; A Handbook for Practitioners of Medicine. By Fletcher Gardner. St. Louis, C. V. Mosby Company, 1916. 418 pp. 46 illus., 9 × 6 in., cloth, \$4.

This handbook is intended to provide a plain non-technical exposition of the duties of a health officer by one familiar with his needs experienced in the routine and emergencies of the local sanitary service, published in a single volume. The second edition is thoroughly revised. An appendix gives schemes for sanitary survey of cities, public buildings, and schools.]

MEMBERSHIP

NEW MEMBERS

The following list comprises the names of those persons who became members during the period of Mar. 10, 1918, to Apr. 10, 1918.

ADAMS, NOAH.....Geol., E. N. Gillespie & Co., Box 1875, Tulsa, Okla.
 ALVAREZ, PEDRO.....Asst. Met., American Smelt. & Refin. Co., Blue Hill, Maine.
 BARTRAM, JOHN G., Pet. Geol., Roxana Petroleum Co. of Oklahoma, Cheyenne, Wyo.
 CHANEY, S. E.....Supt., Arizona Binghamton Copper Co., Stoddard, Ariz.
 CLEVELAND, EARL C.....Mgr., Deadwood Min. Co., Mogollon, N. M.
 DENNIS, HOWARD B.....Min. Engr., Empire Mines, Grass Valley, Cal.
 FOWLER, ARTHUR A., Partner, Rogers, Brown & Co., 30 Church St., New York, N. Y.
 FRIEDMAN, L. A.....Pres. and Gen'l Mgr., Rochester Mines Co., Lovelock, Nev.
 GUIBERSON, S. ALLEN, JR.....923-24 I. N. Van Nuys Bldg., Los Angeles, Cal.
 KROHN, ARTHUR.....Mine Supt., Missouri Metal Corp., Mine La Motte, Mo.
 KURSELL, H. A., Mgr., Altai Mines Ltd., Zmeinogorsk, Altai Gov't, Siberia, Russia.
 LANE, L. RAY.....Mine Examinations, Galiano 24, Aptd. 1066, Havana, Cuba.
 LEDEBOER, JEREMIAS HENDRIKUS, Chief Mech. Engr., Broken Hill Proprietary Co.,
 Ltd., Newcastle, N. S. W., Australia.
 LILLIGREN, J. M....Mill Supt., Missouri Metals Corp., Mine La Motte, Mo.
 MAGRAW, R. M.....Gen'l Supt., United States Fuel Co., Hiawatha, Utah.
 MOORE, HOWARD WARREN...Engr. of Mines, Tungsten Mines Co., Kingman, Ariz.
 MURRAY, MALCOLM S., Chief Engr., Pennsylvania Bituminous Mutual Assoc.,
 422 Mifflin St., Huntingdon, Pa.
 NORDON, JOSEPH A.....Asst. Supt., Utah Apex Min. Co., Bingham Canyon, Utah.
 SCHILOWSKY, IGNACE, Met.....43 Baldwin Street, Bridgeport, Conn.
 SHAW, EUGENE WESLEY.....Geol., U. S. Geological Survey, Washington, D. C.
 TREBILCOCK, JOHN PERRY.....Mining Supt., Big Ledge Copper Co., Huron, Ariz.
 TUCKER, W. BURLING.....Chief Field Asst., California State Min. Bureau,
 512 Union League Bldg., Los Angeles, Cal.
 UDDEN, JON A., Geol.....Austin, Tex.
 WAITE, VICTOR R....Gen'l Mgr., Interstate Clay Co., Box 454, Columbia, S. C.
 WHYTE, W. DEBURGH.....901 Lexington Ave., New York, N. Y.
 WOODUL, J. R., Asst. to Gen'l Mgr., American Smelt. & Refin. Co.,
 1108 Mills Bldg., El Paso, Tex.

Associates

BATCHELDER, W. O.....Mgr., Power & Min. Dept., General Electric Co.,
 1022 Monadnock Bldg., Chicago, Ill.
 JOSEY, R. A., Oil Producer.....Box 461, Tulsa, Okla.
 JOYCE, EDWIN.....Assay & Mill Foreman, Cleveland Min. & Mill. Co.,
 Springdale, Wash.
 MUIR, J. MALCOLM.....Mgr., Metallurgical and Chemical Engineering,
 239 W. 39th Street, New York, N. Y.
 PAIX, EDMOND C. M., Oil Refiner, Paix & Co., 4 Rue de Petrograd, Paris, France.
 SWEET, BERTHOL GUY, Cashier, St. Louis Smelt. & Refin. Co., Collinsville, Ill.

Junior Associates

INGERSOLL, GUY E., Student, Minnesota School of Mines, Minneapolis, Minn.
 JOHNSTON, JOHN M.....Student, Pennsylvania State College, State College, Pa.
 LING, T.....Asst. Engr., Burma Mines Ltd., Burma, India.
 QUINN, HOWARD E.....Student, School of Mines, University of Minnesota,
 Minneapolis, Minn.
 TIZARD, WILLIAM ESSEN.....Student, Lehigh University, So. Bethlehem, Pa.

*Change of Status**Junior to Member*

DOLMAN, PHILLIPS BROOKS..... Geol., The Carter Oil Co., Tulsa, Okla.

WISE, ALFRED L..... Leonard Sales Co., Inc., 28 East 63d St., New York, N. Y.

Total Membership, Apr. 10, 1918..... 6730**CANDIDATES FOR MEMBERSHIP**

APPLICATION FOR MEMBERSHIP.—The Institute desires to extend its privileges to every person to whom it can be of service. On the other hand, it is not desirable that persons should be admitted to membership in classes for which they are not qualified. Members of the Institute can be of great service if they will make a practice of glancing through the list of applicants and promptly notifying the Committee on Membership, or the Secretary of the Institute, if any persons whom they think should not be classified in accordance with the list given.

Applications Lacking Endorsement

Applications for membership have been received from Mr. Hogg, and Mr. Teale, whose records are given below. These applications lack the necessary number of endorsers, but since these candidates live at some distance from the headquarters of the Institute, their records are published here in order that any members who are acquainted with them may be advised of the circumstances and may have an opportunity of writing to the Secretary endorsing these candidates.

*Member***James Hogg, Euboea, Greece.**

Proposed by P. D. Ahier.

Born 1871, Lanarkshire, Scotland. Hutchesontown Grammar School, Glasgow. Glasgow Technical College. Member, Institute of Min. and Met. and Federated Institute of Min. Engrs. 1890-95, min. apprentice, McCreaths & Stevenson, Glasgow. 1895-97, Underground Colliery Mgr., Podmore Hall Collieries, Staffordshire. 1897-1904, Mines Mgr., Aznalcollar Mines, Seville Sulphur & Copper Co., Seville, Spain. 1904-11, Mgr., Heredia Lead Mines, Linares, Spain. 1911-17, Mgr., Anglo-Greek Magnesite Co., Ltd.

Present position: Director and Mgr., Anglo-Greek Magnesite Co., Ltd.

*Associate***James Willie Teale, Euboea, Greece.**

Proposed by P. D. Ahier.

Born 1882, Leeds, England. 1886-90, General Education, Leeds School Board. 1890-95, Ossett School, near Wakefield. 1895-1902, Ossett Technical School, full engr. course, science and art, South Kensington, obtaining Advanced Certificates. Correspondence courses. 1898-1903, Apprenticed to Bradley & Craven Ltd., Engrs., Iron & Brass Foundries, Wakefield, England. 1904-06, asst. to mech. and elec. engr. Old Roundwood Collieries, Wakefield, England. 1907, asst. to mech. and elec. engr., Hoyland Lilkstone Collieries, Ltd., Barnsley. 1908, asst. to mech. and elec. engr., Bullcroft Main Collieries, Doncaster, England.

Present position: Mech. Engr., The Anglo-Greek Magnesite Co., Ltd.

The following persons have been proposed during the period Mar. 10, 1918, to Apr. 10, 1918, for election as members of the Institute. Their

names are published for the information of Members and Associates, from whom the Committee on Membership earnestly invites confidential communications, favorable or unfavorable, concerning these candidates. A sufficient period (varying in the discretion of the Committee, according to the residence of the candidate) will be allowed for the reception of such communications, before any action upon these names by the Committee. After the lapse of this period, the Committee will recommend action by the Board of Directors, which has the power of final election.

Members

Arthur Chapman Adair, Crystal, W. Va.

Proposed by C. A. Cabell, Howard N. Eavenson, E. O'Toole.

Born 1893, Lurich, Va. 1908-11, Narrows High School, Narrows, Va. 1911-12, Concord State Normal School, Athens, W. Va. 1912-13, Virginia Polytechnic Institute, Blacksburg, Va. 1913-15, Rodman and Instrumentman, Elk Horn Coal Corp'n. 1916, Asst. Engr., Carbon Coal Co. and associate companies, Carbon, W. Va. 1916-17, Supt. of Constr. 1917, Engr. in charge, and special work on reports for Vico-pres., Carbon Coal Co., Carbon, W. Va.

Present position: Min. Engr., Crystal Coal & Coke Co. and The Thomas Coal Co.

James Hobart Allport, Barnesboro, Pa.

Proposed by R. V. Norris, W. J. Richards, E. W. Parker, S. A. Taylor.

Born 1874, Philipsburg, Pa. 1889, Various courses from private instructors; High School, Philipsburg, Pa. 1889-93, Eng. of Constr., Pennsylvania R. R. Co. 1893-95, Benton Coal Co., Hastings, Pa. 1895-1900, General Min. Engrg. Practice. 1900-10, Cons. work generally; Northern Cambria Street Ry. Co.; Reese Hammund Fire Brick Co.; Allport Coal Min. Co.; Huntingdon Clearfield Tel. Co.; Baily Heater Co.; Pennsylvania R. R. Co. and numerous others. 1910-12, General cons. practice; N. J. Min. & Mfg. Co. and Colonial Coal & Coke Co. 1912-14, Pres. Clinchfield Coal Corp. and affiliated companies.

Present position—1914 to date: Cons. Min. Engr., Big Sandy Coal Co.; Old Dominion Power Co.; Brickford Fire Brick Co.; Rich Hill Coal Co.

Harry Arnold Baker, Camp Wadsworth, S. C.

Proposed by W. P. Gage, C. A. Allen, J. S. Shaw, F. Julius Fohs, G. H. Wilcox.

Born 1872, Pittsburgh, Pa. 1904-07, Grad., Trinity Univ., Waxahachie, Tex., M. S. 1913, Reynolds College, C. E. 1907-09, Pharmaceutical Chem., Weatherford Drug Co., Weatherford, Tex. 1909-13, Prof., Science and Mathematics, Reynolds College, Albany, Tex. 1913-15, Prof., Chemistry and Physics, Midland College, Midland, Tex. 1915-16, Head of Science Dept., Wichita Falls High School, Wichita Falls, Tex. 1916-17, Principal and Instructor of Science, Vernon Texas High School. 1917-18, Capt., 142d Infantry, U. S. N. G.

Present position: Capt., 53d Pioneer Infantry, U. S. Army.

Robert Clinton Baker, Nacozari, Son., Mex.

Proposed by H. T. Hamilton, H. H. Retter, William B. Cramer.

Born 1882, Taunton, Mass. 1900, Taunton High School, Taunton, Mass. 1900-03, Univ. of Maine. 1903-06, Engr., Bangor & Arroostook R. R. 1906-07, Engr. of Constr., Southern Ry., Birmingham, Ala. 1907, Draftsman, Tenn. Coal, Iron & R. R. Co., Ensley, Ala. 1907-09, Engr. of Constr., Smelters Acid Plant, Tenn. Copper Co. 1909-11, Min. Engr., Miami Copper Co. 1911-12, Sales Engr., M. H. Treadwell Co., New York, N. Y. 1912-17, Salesman, New York Life Insurance Co., Globe, Ariz.

Present position—1917 to date: Min. Engr., Mech. Engr. and Draftsman, Moctezuma Copper Co.

Robert Stephens Beall, Canon City, Colo.

Proposed by Arthur Thacher, Arthur J. Hiester, Russell B. Paul.

Born 1883, Galveston, Tex. 1898-99, Private instr. in chem. 1899-1900, Special course in chem., physics and math., Denver Normal & Preparatory School, Denver, Colo. 1900-05, Asst. Chem. and Chem., Western Chemical Mfg. Co.,

Denver, Colo. 1905-10, Chem. 1910-16, in charge of Ore Testing Plant. 1916-18, Acting Supt. of all operations at Canon City Plant, Empire Zinc Co., Canon City, Colo.

Present position: Supt., Canon City Plant, Empire Zinc Co.

Earl Wilkerson Brooks, Beaver, Pa.

Proposed by Richard R. Hice, W. E. Fohl, E. J. Taylor.

Born 1879, Venango Co., Pa. 1885-91, Common school, Bradford, Pa. 1891-94, Common school, Beaver, Pa. 1894-97, Beaver High School. 1897-98, Geneva College, Beaver Falls, Pa. 1898-99, Beaver College, Beaver, Pa. 1899-1904, Min. Eng. with Selwyn M. Taylor, Pittsburgh, Pa. 1904-09, Chief Min. Eng., with Manufacturers Coal & Coke Co., in Mo. and Iowa. 1909-13, Min. Eng., with John M. Rayburn, Pittsburgh, Pa. 1913, Min. Eng., Caribbean Coal Co., Venezuela, S. A. 1913-17, Min. Eng., with John M. Rayburn.

Present position: Min. Eng., Inland Collieries Co.

George William Brymer, Scranton, Pa.

Proposed by Eli T. Conner, Charles Dorrance, R. Y. Williams.

Born 1871, New York, N. Y. Wilkes Barre, Pa., High School. 1893-95, Special course in math. and science, Wyoming Seminary, Kingston, Pa. 1899-92, Lehigh Coal Co. and other individual companies. 1902-10, Eng. and Supt., Pennsylvania Coal & Coke Co., and others. 1910-12, Farming, Gwynedd Valley, Pa. 1912-14, Supt. Tenn. Coal, Iron & Railroad Co. 1914-17, Eng., Rochester & Pittsburgh Coal & Iron Co., and allied companies.

Present position: Asst. Engr. to Eli T. Conner.

Frederick William Bunyan, Sacramento, Cal.

Proposed by Ray Hawley, J. C. Branner, Welton J. Crook.

Born 1879, London, Eng. 1892-94, Chem., Mech. and Math., London. 1894, Gained London County Council Intermediate Scholarship in open exam. (350 Competitors). 1895-97, Tech. Chem. including met. and allied subjects, City and Guilds of London. Tech. College. 1898-99, Egypt. 1899-1900, Upper Nile. 1900-02, Egypt. 1902-04, Central India, with British Forces, chiefly on topographical work. 1904-14, Engaged chiefly in agriculture; chem. and geol. as hobbies. 1914-15, Co-founder and Sec., Industrial Dept., Leopoldina R. R. Co., Ltd., Brazil, involving large amount of preliminary exploration. 1916, Geological exploration in Brazil for Central R. R. of Brazil, with topographical and geological reconnaissance in eight States. 1917-18, Chem., American Magnesite Co., Portersville, Cal.

Present position: Chem., Test Lab., Southern Pacific R. R. Co.

Harry Arthur DeWitt, Chiksan, Chosen

Proposed by James J. Martin, J. S. Bradford, H. A. Stewart.

Born 1883, Kalamazoo, Mich. 1894-1900, Chicago Public Schools. 1909, Heald Eng. College, San Francisco. 1904-08, Eng. and Asst. Supt., S. A. Development Co., Colombia, S. A. 1910-14, Eng. and Assayer, Mines Co. of America, El Rayo Mine.

Present position—1916 to date: Eng. and Cyanide Supt., Chiksan Min. Co.

James Dickson, Darrington, Wash.

Proposed by H. deS. Kennedy, Joseph Daniels, Robert W. Handley.

Born 1881, Marysville, Mont. 1888-98, Butte Public School. 1900-12, Private tutorage in mineralogy and geology. 1899-1902, Boss timberman underground, Boston-Montana Copper Co., Butte, Mont. 1903-05, Sampling and surveying, Amalgamated Copper Co., Butte, Mont. 1905-07, Foreman, Star of the West Mine, Golden Eagle Min. Co., B. C., Canada. 1908-12, Mining and prospecting in Alaska. 1912-15, Shift boss, Alaska Gastineau Min. Co., Juneau, Alaska. 1915-16, Foreman, Gold Bullion Min. Co., Knik, Alaska. 1917-18, Mine Supt., Boston-American Min. Co., Monte Cristo, Wash.

Present position: Mine Supt., Puget Sound Copper Co.

Walter Simmonds Dickson, Arlington, N. J.

Proposed by Bradley Stoughton, G. P. Bartholomew, Pope Yeatman.

Born 1885, Brooklyn, N. Y. 1912, Columbia Univ., E. E. 1908-10, erecting and operating installations, General Electric Co. 1910-12, associated with Mailloux & Knox, Cons. Engrs. of N. Y., interested in isolated plants and equipment both

electrical and mechanical for large public buildings. 1912-15, Asst. to Mr. P. H. Thomas and G. P. Bartholomew, Chile Exploration Co., in electrolytic recovery of copper at Chuquicamata, and reduction of sulphide ores, Braden Copper Co. 1915-17, Resident Engr., DuPont Nitrate Co., Chile.

Present position: Engr., Stoughton Process Co.

Marshall Daniel Draper, Baxter Springs, Kan.

Proposed by E. T. Lednum, P. B. Butler, R. H. Summer.

Born 1875, St. Louis, Mo. 1897, Grad., Colo. State School of Mines, Golden, Colo., E. M. 1897, Contr., Telluric Gold Min. Co., Lake City, Colo. 1898, Assayer, Surveyor, Kennett Min. Co., Ennis, Mont. 1899-1900, Assayer and Chem., Draper and McLeod, Denver, Colo. 1900-03, Supt., East Notaway Mine, Central City, Colo. 1904-05, Supt., Minn. Connor Min. Co., Chloride, Ariz. 1906-07, Mgr., Negociacion Min. de La Lombardia, Mich., Mex. 1908-09, Mgr., 50 Gold Mines Corp., Black Hawk, Colo. 1910, Eng., Empire Zinc Co., Denver, Colo. 1910-12, Draper and Gross, Min. Engrs., Denver, Colo. 1913, Supt., Tuscarora Cons. Min. Co., Tuscarora, Nev. 1914, Exam., Nicaragua, Alaska, etc. 1915-16, Mgr., Mina Mexico Min. Co., Sonora, Mex.

Present position—1917 to date: Mgr., Anna Beaver Mine.

Thomas George Fear, Harmarville, Pa.

Proposed by Richard R. Hice, W. E. Fohl, E. J. Taylor.

Born 1884, Blackridge, Pa. 1890-1899, Commons schools, Eckley, Pa. 1899-1901, Hazleton, Pa., High School. 1901-02, Mining and Mech. Inst., Freeland, Pa. 1902-06, Lehigh Univ., Mech. Engrg. 1906-08, Mech. Engr., Birch Run Coal Co., Minersville, Pa. 1908-09, Eng., Min. Dept., Tenn. Coal Iron & R. R. Co., Birmingham, Ala. 1909-10, Resident Engr., Docena mine, Tenn. Coal Iron & R. R. Co., Birmingham. 1910-12, Div. Supt., Whitwell mines, Tenn. Coal Iron & R. R. Co. 1912-17, Supt., Bay View Div., Tenn. Coal Iron & R. R. Co.

Present position: Gen'l Supt., coal mines, Inland Collieries Co.

Thaddeus Remy Goldsborough, Washington, D. C.

Proposed by S. H. Ball, Donald B. Doyle, Charles W. Boise.

Born 1888, Cincinnati, Ohio. 1909-12, Swarthmore, Dartmouth and Colorado School of Mines. 1912-14, Missouri School of Mines, B. Sc. 1914, Office, Dominion Reduction Co. 1915, Office, Tonopah Ex. Min. Co.; Mogul Min. Co.

Present position—1916 to date: Engr. Prospector (Diamonds) Société Internationale Forestière et Minière du Congo.

Valentin John Gudkov, New York, N. Y.

Proposed by Thomas E. Sturtevant, Louis D. Huntoon, Bradley Stoughton.

Born 1884, Russia. 1893-1903, Gymnasium, Helsingfors, Finland. 1903-04, Min. Institut, Petrograd, Russia. 1904-05, Grad., Candidat d'Ingénieur. 1905-08, Grad., Min. Institut, Petrograd, Russia, M. E. 1909, Supt., Chem. Lab., Vidizky Wks., Russia. 1910-12, Foreman, blast furnaces, Briansk Wks., Russia. 1912-13, Mgr., blast furnaces, Bogoslovsk Min. Co., Russia. 1914-15, Director, Alapaievsk Min. Wks. 1916-17, Representative at Russian Government Min. Dept., Washington, D. C. Resigned; refused to recognize Bolshevik government.

Present position: Unattached.

Philo Halsia Halleck, Bisbee, Ariz.

Proposed by Arthur Notman, Gerald F. G. Sherman, Ezra B. Rider.

Born 1889, Herington, Kan. 1908-13, Min. Dept., Univ. of Kan., B. S. 1913, Mucker, Copper Queen Cons. Min. Co., Bisbee, Ariz. 1914, Engr. Dept., Copper Queen Cons. Min. Co., Bisbee, Ariz. 1915, Smith and Ziesemer, Min. Engr. 1916-17, Div. Engr., Phelps-Dodge Corp., Copper Queen Branch, Bisbee, Ariz.

Present position: Chief sampler, Phelps-Dodge Corp.

Ole Hallingby, Calumet, Mich.

Proposed by C. H. Benedict, John Knox, Ocho Potter.

Born 1871, Osage, Iowa. 1899, Univ. of Chicago, Ph. B. 1907, Michigan College of Mines, E. M. 1899, Librarian and Musician, concert band, Chicago. 1900-01, Assayer, Lake Superior Smelt. Works, Dollar Bay, Mich. 1901-09, Draughtsman, Calumet & Hecla Min. Co.

Present position—1909 to date: Supt., LaSalle Copper Co.

Charles Ruffin Hook, Middleton, O.

Proposed by R. B. Carnahan, Jr., William H. Shearman, Thomas T. Read.

Born 1880, Cincinnati, O. 1898, Grad., Walnut Hills High School, Cincinnati, O. 1898-1902, Office boy to rolling mill foreman, U. S. Steel Corp., 1902-04, Night supt.; 1904-11, Asst. gen'l supt., 1911-16, Gen'l supt., American Rolling Mill Co., Middleton, O.

Present position—1916 to date: Vice-pres., Operating Div., American Rolling Mill Co.

Frederick Boren Hyder, San Francisco, Cal.

Proposed by C. Colcock Jones, B. L. Thane, Charles A. Hyder.

Born 1882, Carter Co., Tenn. 1898-99, Univ. of Colorado, E. E. 1899-1903, Colorado School of Mines, E. M. 1903-05, U. S. Deputy, Mineral Survey, Colorado and Nevada. 1905-08, Hyder & Hyder, Sonora, Mex. 1909, Supt. min. and mill., Dawson Min. Co., Sonora, Mex. 1909, Engr., Minneapolis Copper Co., Sonora, Mex. 1909, Engr., Mazapil Copper Co., Sonora, Mex. 1910, Supt., C. M. de Con Virginia, Sonora, Mex. 1910-11, Mill Supt., C. M. de Durazno Tetamoas, Chih., Mex. 1911-12, Hyder & Hyder, Sonora, Mex. 1912-13, Exploration in Central America. 1913-16, Geol., Alaska Gastineau Min. Co., Juneau, Alaska.

Present position—1916 to date: Chief Engr., B. L. Thane Exploration Dept.

Walter Raymond Judson, Santiago, Chile.

Proposed by Louis A. Wright, William Braden, Spruille Braden.

Born 1882, Dayton, O. Common and high schools, Dayton, O. 1899-1903, Ohio State Univ., M. E. 1903-04, Draftsman, Moctezuma Lead Co., Santa Barbara, Mex. 1904-05, Machine shop, Hocking Valley R. R., Columbus, O. 1905, Asst. supt., concentrator, Moctezuma Lead Co., Santa Barbara, Mex. 1905-06, Mine foreman and engr., Tezuitlan Copper Co., Puebla, Mex. 1906-07, Test engr. and draftsman, Cia. Minera de Penoles, Mapimi, Mex. 1907-13, Sales engr., Victor M. Braschi, Mex. D. F. 1913-14, Supt., Cinco Minas Co., Magdalena, Jalisco, Mex. 1914-16, Salesman, John A. Roebling's Sons Co., So. America and St. Louis, Mo.

Present position—1916 to date: District Mgr., Allis-Chalmers Mfg. Co.

Graham Marienius Kindseth, Miami, Ariz.

Proposed by George H. Booth, L. D. Ricketts, L. O. Howard.

Born 1892, Minneapolis, Minn. 1911-13, Univ. of Minn. 1914-15, Univ. of Florida. 1915-16, Univ. of Arizona, B. S. 1916-17, Chem. Assayer, International Smelt. Co.

Present position—1917 to date: Testing Engr., International Smelt. Co.

George W. Lucas, Tulsa, Okla.

Proposed by John R. Suman, R. A. Conkling, F. B. Plummer, C. A. Hammill.

Born 1885, Bedford, Ia. No technical education. 1906-15, Topographer, U. S. Geological Survey.

Present position—1915 to date: Geol., Roxana Petroleum Co. of Okla.

Alexandre Lheraud, Spain.

Proposed by A. R. Ledoux, F. Ledoux, A. Chastel.

Born 1886, Macon, France. To 1906, Lycée Henri IV, Paris, France, B. Sc. 1906-10, Ecole Nationale Supérieure des Mines de Paris. 1916, Diploma of Min. and Civ. Engr. 1910-14, 2d engr., in coal mine; 1914-16, Chief engr., Société Minière et Métallurgique de Penarroya. Experience in fire damp, fires, electric motor power, carbonization, etc. Member, Société de l'Industrie Minérale.

Present position—1917 to date: Chief Engr., Minas El Soldado, Société Minière et Métallurgique de Penarroya.

Leonard Caswell McCloud, Midas, Nev.

Proposed by John V. N. Dorr, Lee D. Dougan, H. N. Spicer.

Born 1891, Idaville, Ind. 1908, Wiley High School, Terre Haute, Ind. 1908-13, Indiana State Normal, B. A. 1913-16, Purdue Univ., B. S. 1916-17, Millman, Elko Prince Leasing Co., Midas, Nev.

Present position: Investigator, Elko Prince Leasing Co.

Angus Benjamin McLeod, Butte City, Mont.

Proposed by Henry D. Morse, W. S. Grether, Charles Bocking.

Born 1873, Kings Co., N. Y. Grade school. 1893-1908, various occupations from shoveler to foreman, Anaconda Copper Mining Co.

Present position—1909 to date: Mine Supt., Butte & Superior Mining Co.

John Leopold Mauch, Brooklyn, N. Y.

Proposed by Walter H. Aldridge, Wilbur Judson, Forest Rutherford.

Born 1877, Freiberg, Baden, Germany. English High and Manual Training School, Chicago, Ill. Private study in engineering and science. 1899-1900, Designer of min. machinery, Simpson Machinery Co., Chicago, Ill. 1900-03, Designer on Washoe mill and smelter, Anaconda Copper Min. Co., Anaconda, Mont. 1903-06, Designer and checker, Cerro de Pasco Min. Co.; Michigan Smelt. Co. 1906-07, Engr., smelter design, Balaklala Cons. Copper Co., Coram, Cal. 1908-09, Engr., design and constr., stamp mill and cyanide plant, Goldfield Cons. Mines Co., Goldfield, Nev. 1909-10, Chief draftsman, design of Tooele smelter, International Smelt. & Refin. Co., Salt Lake City, Utah. 1910-11, Engr., smelter design, Mason Valley Mines Co., Thompson, Nev. 1911-12, Engr., mine and mill design, Inspiration Cons. Copper Co., Los Angeles, Cal. 1912-15, Engr., design for Repath & MacGregor, on smelters, Calumet & Arizona Min. Co., United Verde Copper Co. and Arizona Copper Co. 1915-16, Engr., designing constr., Cons. Arizona Smelt. Co., Humboldt, Ariz.

Present position: Engr., design of Caletones smelter, Braden Copper Co.

Ellis Landerbaugh Mellott, Taltal, Chile.

Proposed by P. F. Holstein, F. S. MacGregor, G. B. Street.

Born 1886, Everett, Pa. 1909-13, Grad., Pennsylvania College, B. S. 1913, Chem., E. I. du Pont de Nemours Powder Co.

Present position—1914 to date: Chem., Du Pont Nitrate Co.

Harold Carl Miller, Bishop, Cal.

Proposed by Alvin B. Carpenter, A. B. W. Hodges, F. B. Close.

Born 1889, Saginaw, Mich. 1908-11, Michigan College of Mines, Houghton, Mich., B. S., E. M. 1911, Asst. Engr., Victoria Copper Co., Victoria, Mich. 1912, Supt., Pilot Knob Min. Co., Gottville, Siskiyou Co., Cal. 1913, Engr., Daniels and Osmont, San Francisco, Cal. 1913-17, Engr. and constr. operations, Bishop, Inyo Co., Cal.

Present position—1917 to date: Supt., Round Valley Tungsten Co.

William Gordon Mitchell, Brooklyn, N. Y.

Proposed by John Bonsall Porter, John W. Bell, Frank D. Adams.

Born 1888, Port Hope, Ont., Can. 1913, McGill Univ., B. Sc., Montreal. 1914, McGill Univ., M. Sc. 1911-13, Supt. railroad constr., Ont., Can. 1914, Eng. Asst., Montreal Tunnel & Terminal Co., Montreal. 1914-16, Research Engr., Forest Products Laboratories of Can., Montreal.

Present position—1916 to date: Min. Engr., R. Martins & Co.

Ralph Switzer Moore, El Paso, Tex.

Proposed by Kuno Doerr, P. A. Mosman, Frank M. Smith.

Born 1876, Portsmouth, O. 1899, Cornell Univ., M. E. 1900-02, Asst. supt., foundry and machinery wks. 1902-03, Engr., Garrett Cromwell Co., Cleveland, O. 1903-04, Engr., Colorado Fuel & Iron Co., Pueblo, Colo. 1904-05, Engr., C. Q. Smelter, Douglas, Ariz. 1905-07, Engr., Boston Colorado smelter, Denver, Colo. 1907-08, Engr., Jackson Iron & Steel Co., Jackson, O. 1908-12, Member, Pearce & Moore, Mech. & Met. Engrs., London, England. 1912-14, Engr., Pennsylvania Steel Co., Harrisburg, Pa. 1914-18, Engr., El Paso Smelting Wks.

Present position: Chief Engr., El Paso Smelting Wks.

Everett Hiram Mott, Peru, S. A.

Proposed by Stuart L. Rawlings, E. E. Barker, J. T. Glidden.

Born 1885, Yazoo City, Miss. 1905, Grad., Univ. of Vermont, B. S. 1905-06, Sampler in smelter, Bingham Cons. Min. & Smelt. Co. 1906-07, Chem. and surveyor, Nevada Cons. Copper Co.; Chief Chem., Giroux Cons. Mines Co. 1908-09, Sampling mill foreman, furnace man, converter skimmer and blast-furnace foreman,

Cerro de Pasco Min. Co. 1910-15, General foreman smelter, U. S. Metal Refin. Co.
Present position—1915 to date: Smelter Supt., Soc. Minera Backus y Johnston del Peru.

Fritz August Mueller, Omaha, Neb.

Proposed by P. A. Mosman, Jesse O. Betterton, Walter T. Page.

Born 1891, Marshalltown, Iowa. 1907-10, Fremont College, Fremont, Neb., A. B. 1913-15, Chem. engr. course, including summer school, Armour Inst. of Tech. 1915, Chem. engr. course, Univ. of Ill. 1910-12, Clerical work, Omaha Packing Co., Omaha, Neb. 1912-13, Clerical work, Morris & Co., So. Omaha, Neb. 1915, Instructor, Afton High School, Afton, Iowa.

Present position—1915 to date: First Asst. Chem., Union Pacific Railroad Co.

Howard Frank Nash, Bartlesville, Okla.

Proposed by George D. Morgan, Hayes W. Young, Welton J. Crook.

Born 1885, Sheldon, Iowa. 1904-06, Elec. engr., Leland Stanford Jr. Univ. 1907-10, Geol. and min., Leland Stanford Jr. Univ., A. B. 1910-12, General placer and metal min. experience. 1912, Oil flotation and mine exam., James M. Hyde, Palo Alto, Cal. 1913-14, Geol. and field mgr., Caribbean Petroleum Co., Caracas, Ven. 1914-16, Farming, Polson, Mont. 1916-17, Geol., Empire Gas & Fuel Co., Bartlesville, Okla.

Present position: Geol., Compania Emmex de Petroleo y Gas S. A., subsidiary of Empire Gas & Fuel Co.

Frank John Neiman, Shenandoah, Pa.

Proposed by J. T. Henry, T. M. Dodson, H. D. Kynor.

Born 1885, Ashland, Pa. 1901, High School, Ashland, Pa. 1903, International Correspondence School, Scranton, Pa. 1901-06, Engrg. Dept., Lutz & Co., Park Place, Pa. 1906-12, Engrg. Dept., Lehigh Valley Coal Co., Mahanoy City, Pa. 1912-18, Div. Eng., Lehigh Valley Coal Co., Mahanoy City, Pa.

Present position: Supt., Locust Mountain Coal Co.

Walter L. Penick, Salt Lake City, Utah.

Proposed by H. W. Hardinge, R. B. T. Kiliani, V. A. Stout.

Born 1890, Montreal, Can. 1897-1905, Graded School, La Fayette, Ind. 1905-09, Grad., High School, La Fayette, Ind. 1909-11, Ohio State Univ. 1911-12, Mucker and mill operator. 1912-14, Washington State College, B. S. 1914, Laboratory asst., flotation research, Butte & Superior Copper Co. 1914-15, Chief assayer and chem., Globe Cons. Min. Co. 1915-17, Flotation met. and mill foreman, experimental and practical operation, Mountain Copper Co., Ltd. 1917-18, Flotation met. and mill foreman, experimental plant for flotation research, Granby Cons. M. S. & P. Co.; discovered use of sea water as successful flotation reagent.

Present position: Eng., Hardinge Conical Mill Co.

Evert LeRoy Rankin, Altoona, Kan.

Proposed by A. R. Campbell, S. D. Callaway, W. H. Eardley.

Born 1886, near Kirksville, Mo. 1901-05, Student, Iola, Kan., High School; Chem., International Correspondence School. 1906-08, Laborer and asst. chem., Lanyon Zinc Co., Iola, Kan. 1908-10, Iola Wholesale Fruit Co., Iola, Kan., represented L. Vogelstein and Beer-Sondheimer at zinc smelt., Iola, Kan. LaHarpe, Kan., Nevada, Mo. 1912-13, Private mfg. business, Kan. City, Mo. 1914, Butte Superior Min. Co., Butte, Mont. 1915, Big Four Exploration Co. and Western Metals Co., Salt Lake. 1916-17, Supt., U. S. Smelt. Co., Zinc Plant, Checotol, Okla.

Present position: Supt., Zinc Plant, U. S. Smelt. Co.

Charles Rees, Sterlington, N. Y.

Proposed by C. Colcock Jones, B. L. Thane, Charles A. Hyder.

Born 1877, Pittsburgh, Pa. 1900, Practical work, Minn. Land Survey. 1903, Advanced geol., Univ. of Wis. 1900-03, Land surveys, U. S. Steel Corpn. 1903, Univ. of Wis. 1904-11, Geol. work, U. S. Steel Corpn. 1911-15, Gen. mine examination. 1915, Geol., U. S. Steel Corpn. 1916, Geol., American International Corpn. 1917, Geol., Midvale Steel & Ordnance Co.

Present position: Supt., Ramapo Ore Co.

Almon Fulton Robertson, Butte, Mont.

Proposed by Julius H. Warner, P. F. Minister, Oscar Rohn.

Born 1889, Castle, Mont. 1895-1902, Livingston Public School, Livingston, Mont. 1902-06, Park Co. High School, Livingston, Mont. 1906-11, University of Wisconsin, B. S. 1909-11, summers, Charles T. Sacket, Civ. and Min. Engr. 1911-13, County Surveyor, U. S. Mineral Surveyor, Park Co., Mont.

Present position—1913 to date: Engr., East Butte Copper Min. Co.

John Clifford Rogers, Copper Cliff, Ont.

Proposed by H. S. Drinker, Howard Eckfeldt, Benjamin L. Miller.

Born 1886, Brooklyn, N. Y. 1900, Lyons Union High School, Lyons, N. Y. 1904, Lyons High School, Lyons, N. Y. 1905-09, Cornell Univ., C. E. 1909-11, Special, Lehigh Univ. 1911-12, Draughtsman and estimator, Guerber Engineering Co., Bethlehem, Pa. 1912-14, Sampler, Canadian Copper Co., Copper Cliff, Ont. 1914-17, Chief sampler and field engr., Canadian Copper Co., Creighton Mine, Ont.

Present position—1917 to date: Exploration Engr., International Nickel Co.

Beach Helme Stockett, Shenandoah, Pa.

Proposed by J. T. Henry, T. M. Dodson, H. D. Kynor.

Born 1888, Bethlehem, Pa. 1905, Mauch Chunk High School, International Correspondence School, C. E. 1905, Civ. Engr., William H. Duhant, Reading, Pa. 1906-13, Engrg. Corps, Constr. Works, Breaker Inspection, Foreman of storage yard, Lehigh Coal & Navigation Co. 1913-17, Supt., Locust Mountain Coal Co., Shenandoah, Pa.

Present position: Gen. Supt., Dodson Anthracite Interests.

Alford Roos, Tucson, Ariz.

Proposed by F. C. Alsdorf, Harry H. Miller, A. A. Wren, Fred. G. Farish.

Born 1882, Taylors Falls, Minn. 1907-09, Battle Creek High School, Battle Creek, Mich. 1909-12, Mich. College of Mines, Houghton, Mich. 1912-13, Drafting and instrument man in field, J. P. Wolf, St. Paul, Minn. 1913-14, Leasing small mines, Silver City dist., N. M. Custom Assay Laboratory, Bayard, N. M. 1914-17, Independent operator producing mines, Organ Dist., operating Memphis, Excelsior and King mines; Pres., Memphis Leasing Co., Inc. 1917, Cons. Min. Engr., Tucson, Ariz.; geol., mill., smelt. and met. reports. Retained as overseeing mgr. small dev. operations. 1913-17, U. S. Naval Service Honorable Release.

Present position: Pres. and Gen. Mgr., Pima Smelt. & Refin. Co.

Joseph Barnes Stratton, Potrerillas, Chile.

Proposed by L. R. Wallace, W. L. DuMoulin, J. F. Hanst.

Born 1884, Nevada, Mo. 1900, High School, Nevada, Mo. 1902-03, Morrisville College, Morrisville, Mo. 1905-08, Acct., Detroit Copper Mining Co. 1908-10, Collection Teller, First National Bank of Seattle, Wash. 1911-12, Cashier, First National Bank, Centralian, Okla. 1912-16, Mine acct., Inspiration Cons. Copper Co. 1916-17, Chief clerk and mine acct., United Eastern Min. Co., Oatman, Ariz.

Present position—1917 to date: Chief clerk, Andes Copper Min. Co.

Ernest Edgar Thum, Salt Lake City, Utah.

Proposed by J. B. S. McIntosh, A. H. Richards, F. G. Moses.

Born 1884, Harrisonville, Mo. 1902-06, Colo. School of Mines. 1906-07, Engrg. dept., Anaconda Copper Min. Co., Anaconda and Arcot Falls. 1908-09, Chief civ. engr., Tooele Plant Constr., Tooele, Utah. 1910-14, Engr. in charge of constr., Arcot Falls Plant, Anaconda Copper Min. Co. 1915-17, Asst. Prof. Met., Univ. of Cincinnati.

Present position: Western Editor, *Met. and Chem. Engr.***Frederick John Wettrick, Juneau, Alaska.**

Proposed by B. L. Thane, Angus Mackay, E. V. Daveler.

Born 1883, New Carlisle, Ohio. 1902, Valparaiso Univ., Ind., B. Sc., B. A. 1903-06, Univ. of Washington, Seattle, Wash., M. A. 1907, Eng. on location surveys, Alaska Railroad & Terminal Co., Katalla, Alaska. 1908, Own engr. and surveying office, Juneau, Alaska. 1909-11, Engr., Penn-Alaska Min. Co., Juneau, Alaska. 1910-11, Engr. Ebner Gold Min. Co., Juneau, Alaska. 1911-12-13, Engr. and Mineral Surveyor, Alaska Gastineau Min. Co.

Present position—1913 to date: Maintaining general engineering and surveying office.

William C. White, Weedon, P. Q., Canada.

Proposed by C. W. Cushman, H. C. Heise, E. N. Engelhardt.

Born 1893, Colfax, Wash. 1906-10, Colfax High School, Colfax, Wash. 1911-13, Student in mining, Washington State College. 1914-16, Student in mining, Washington State College. 1910-11, Miner, Knob Hill mine, Republic, Wash. 1913-14, Miner, sampler on examinations, Rainbow mine, Baker Co., Ore. 1916-17, Engr. Weedon mine, Weedon, Que. 1917-18, Mine foreman, Zinc Co., Ltd., Portneuf Co., Que.

Present position: Asst. supt., Weedon mine.

Associates

Paul Livingston Applin, Tulsa, Okla.

Proposed by R. A. Conkling, F. B. Plummer, John R. Suman.

Born 1891, Keene, N. H. 1906-10, Keene High School. 1910-14, Dartmouth College, A. B. 1915-16, Dept. of geol., Yale Graduate School. 1916-17, Instr. in mineralogy, Dartmouth College.

Present position—1917 to date: Geol., Roxana Petroleum Co. of Okla.

Francis Merriman Barnes, Jr., St. Louis, Mo.

Proposed by Thomas T. Read, William H. Shearman, J. H. Polhemus.

Born 1881, Middletown, N. Y. 1899-1903, Hamilton College, A. B. 1906, A. M. 1902, Marine Laboratory, Woods Hole, Mass. 1903-07, Johns Hopkins Univ., M. D. 1907-08, Neurological Clinic, Johns Hopkins Univ. 1907-10, Dir. Clinical Laboratories. (Biological research) Sheppard and Pratt Hospital, Baltimore. 1910-13, Clinical Dir., Government Hospital for the insane, Washington, D. C. 1910-13, Instructor in Neurology and Psychiatry, George Washington Univ., Washington, D. C. 1913-14, Asst. Prof. nervous and mental diseases, St. Louis Univ., St. Louis, Mo. 1913-16, Medical Dir., Glenwood Sanatorium.

Present position—1916 to date: Visiting physician, St. Louis City Hospital; cons. physician, City Sanitarium; and physician to out patients, Washington Univ. Dispensary.

John Gurney Burt, Tulsa, Okla.

Proposed by John R. Suman, R. A. Conkling, F. B. Plummer, C. A. Hammill.

Born 1892, Chicago, Ill. 1911-15, Univ. of Chicago, S. B.

Present position—1916 to date: Geol., Roxana Petroleum Co.

Mureel Edward Carpenter, Tulsa, Okla.

Proposed by John R. Suman, R. A. Conkling, F. B. Plummer, C. A. Hammill.

Born 1892, Olney, Ill. 1916, Univ. of Oklahoma, C. E. 1916-17, Studied geol. and petroleum chemistry, Univ. of Oklahoma. 1916, Summer, asst. county engr., Cleveland Co., Okla.

Present position—1917 to date: Geol. Engr., Roxana Petroleum Co.

Thomas Arthur Gowling, Marquette, Mich.

Proposed by John E. Hodge, Clyde S. Longyear, Percy W. Donovan.

Born 1881, Marquette, Mich. High School. 1898-1905, Stationary steam and elect. engrg., Tri City Ry. and Peoples Powder Co., Rock Island, Ill. 1906-07, Shattuck Arizona Copper Co., Bisbee, Ariz. 1907-09, Field man, E. J. Longyear Co. 1909-11, Representing E. J. Longyear Co., copper country, Mich.

Present position—1911-18: Exploring Engr. and member, E. J. Longyear Co.

Junior Associates

Harry L. Baldwin, Loanda, Angola.

Proposed by Chester W. Washburne, S. H. Ball, Lucius W. Mayer.

Born 1898, Washington, D. C. 1915, Washington High School. 1916-17, Colorado School of Mines. 1915, Summer, computer, General Land Office. 1916,

Summer, farming. 1917, Summer, instrument man on geol. party, Empire Gas & Fuel Co.

Present position: Instrument man on geol. exploration in Africa.

Byron Blackburn Boatright, Golden, Colo.

Proposed by J. C. Roberts, Victor C. Alderson, I. A. Palmer.

Born 1900, Colorado Springs, Colo. 1914-15, Westminster College. 1916, Westminster High School. 1917, North Denver High School.

Present position—1917 to date: Student, Colorado School of Mines.

Neil Enoch Johanson, Golden, Colo.

Proposed by J. C. Roberts, Victor C. Alderson, I. A. Palmer.

Born 1898, Denver, Colo. 1913-15, Eaton High School, Eaton, Colo. 1915-17, San Antonio High School, San Antonio, Tex.

Present position—1917 to date: Student, Colorado School of Mines.

Hubert Wilbur Mara, Rapid City, So. Dak.

Proposed by C. C. O'Harra, W. C. Bochart, F. W. Traphagen, Charles Bentley.

Born 1889, Troy, So. Dak. 1896-1904, Public school. 1904-06, College preparatory, So. Dak. State College. 1908-10, College preparatory and freshman, So. Dak. School of Mines. 1916-18, Sophomore and Junior met., So. Dak. School of Mines. 1906-08, Track foreman, Minn. & St. Louis R. R. Co., 1910-16, Track and extra gang foreman, Minn. & St. Louis R. R. Co. 1917, Homestake Min. Co., Lead, So. Dak.

Present position: Junior Met. Student, So. Dak. School of Mines.

Theodore Marvin, Golden, Colo.

Proposed by J. C. Roberts, Victor C. Alderson, I. A. Palmer.

Born 1899, Billings, Mont. 1917, Grad., Sheldon High School, Sheldon, Iowa.

Present position: Student, Colorado School of Mines.

Loren Dallas Mulford, Golden, Colo.

Proposed by J. C. Roberts, I. A. Palmer, Victor C. Alderson.

Born 1879, Wappelo Co., Ia. 1899-1900, Unemployed. 1901, Colorado School of Mines. 1902-04, Farming. 1905, Business College. 1906-15, Conducted general store, Westminster, Colo.

Present position—1915 to date: Student, Colorado School of Mines.

Russell Johnston Parker, Denver, Colo.

Proposed by J. C. Roberts, Victor C. Alderson, I. A. Palmer.

Born 1897, Olney Springs, Colo. 1912-15, West Denver High School. 1916-17, Univ. of Denver. 1917-18, Colorado School of Mines. 1916, Summer, Bonanza, No. 1 Nederland. 1917, Summer, Alta Mine, Telluride.

Present position: Student, Colorado School of Mines.

Bryant King Rogers, Golden, Colo.

Proposed by J. C. Roberts, I. A. Palmer, Victor C. Alderson.

Born 1897, N. Y. 1906-13, Mt. Hebron grammar school, Montclair, N. J. 1913-17, Montclair High School, Montclair, N. J.

Present position: Student, Colorado School of Mines.

Bei Chen Tsen, Golden, Colo.

Proposed by J. C. Roberts, I. A. Palmer, Victor C. Alderson.

Born 1894, Leiyoung, Hunan, China. 1908-13, Student of Kung Tsen School, Hunan, China. 1913-15, Student, Univ. of Ill., Urbana, Ill.

Present position—1915 to date: Student, Colorado School of Mines.

Change of Status, Junior to Member

Thaddeus Roderick Noon, Peru, Ill.

Proposed by J. A. Ede, Henry W. Nichols, H. A. Buehler, E. A. Holbrook.

Born 1893, Peru, Ill. 1908-13, St. Marys College, St. Marys, Kan. 1913-17, Marquette Univ., Milwaukee, Wis., B. S. 1913-17, Summers, worked under Mr. Ede, chief of mining dept., Illinois Zinc Co., Peru, Ill.

Present position: Asst. to chief of mining dept., Illinois Zinc Co.

William C. Schmidt, Jr., N. Y.

Proposed by Robert Peele, William Campbell, Edward K. Judd.

Born 1890, N. Y. 1904-08, DeWitt Clinton High School, N. Y. 1908-14, Columbia Univ., School of Mines, E. M. 1914, Asst. engr., B. C. Copper Co., Copper Mt., B. C. 1915-16, Mine surveyor. 1916-17, Examining engr., N. Y. & Honduras Rosario Min. Co., San Juancito, Honduras, C. A.

Present position: Unengaged.

Carol John Wakenhut, Tulsa, Okla.

Proposed by C. L. Severy, Arthur C. Terrill, Willard W. Cutler, Jr.

Born 1895, Salina, Kan. 1901-09, Public Schools, Salina, Kan. 1909-13, Salina High School, Salina, Kan. 1913-17, Univ. of Kan., B. S., M. E. 1910, Summer, chainman, Salina, Kan. 1911, Summer, rodman, on location Winnipeg, Salina and Gulf Ry., Salina, Kan. 1912, Summer, asst. to City Engr., Salina, Kan. 1913, Summer, enrg. dept., Watts-Amerman Construction Co. 1914, Summer, asst. to City Eng., Salina, Kan. 1915, Summer, Joplin Dist. 1916, Summer, Instrument and Geol. Asst., Carter Oil Co., Tulsa, Okla.

Present position—1917 to date: Geol., Carter Oil Co.

CHANGE OF ADDRESS OF MEMBERS

The following changes of address of members have been received at the Secretary's office during the period Mar. 10, 1918 to Apr. 10, 1918.

This list together with the list published in Bulletin Nos. 133 to 136, January to April, 1918, and the foregoing list of new members, therefore, supplements the annual list of members corrected to Jan. 1, 1918 and brings it up to the date of Apr. 10, 1918.

ADAMS, HENRY MAJOR.....Asst. to Dept. Engr., Northeastern Dept.,
25 Huntington Ave., Boston, Mass.

ADKINS, H. S.....Gen'l Supt., J. B. Elkhorn Coal Co., Robinson Creek, Ky.

ALBERTSON, M. M.....Teck-Hughes Mines, Ltd., Kirkland Lake, Ont., Canada.

ALINE, PETER A.....Co. C, 316th Supply Trains, Camp Lewis, Wash.

ALLEN, H. H.....Co. D, 8th Reserve Engineers, A. E. F., Care
Postmaster, N. Y.

ANDERSON, BARCLAY G., Co. B, 318th Engineers, Vancouver Barracks,
Vancouver, Wash.

ANDERSON, W. G.....220 Parnassus Ave., San Francisco, Cal.

ARMSTRONG, J. A. B., Andes Exploration Co., of Maine, Casilla 290, Arequipa, Peru.

ARNOLD, JOHN B.....Arnold & Arnold, 606 Lyceum Bldg., Duluth, Minn.

AUSTIN, L. S.....654 Linden Ave., Long Beach, Cal.

BAECHTELD, CHARLES A., Sales Mgr., Lidgerwood Mfg. Co.,
601 Central Bldg., Los Angeles, Cal.

BAILLIE, FRANK S.....Rand Bldg., Baker, Ore.

BELL, L. R.....Co. C, 302d Engineers, U. S. A., Camp Upton, L. I.

BELLIS, A. E., Capt., Ordnance Reserve Corps, Springfield Armory, Springfield, Mass.

BILLICK, DON C.....Ordnance Dept., U. S. Army.

BIRCH, G. H.....Vice-Pres. & Gen'l Mgr., Dan Creek Min. Co.,
160 Broadway, New York, N. Y.

BLEECK, A. W. G., Indo Burma Petroleum Co., Box 132, Rangoon, Burma, India.

BOOTH, L. E.....Co. R, Ordnance Training Camp, Camp Hancock, Ga.

BOWEN, HERBERT P.....Atlanta, Idaho.

BOWMAN, F. C.....Valley, Stevens Co., Wash.

BRADDOCK, HOMER F.....Empire Bldg., Pittsburgh, Pa.

BRASSERT, H. A.....Peoples Gas Bldg., Chicago, Ill.

BREINL, JOSEPH C.....Ingersoll-Rand Co., Painted Post, N. Y.

BRINSMADE, ROBERT B.....Ixmiquilpan, Hgo., Mexico.

BROCKUNIER, S. H., *Engineering & Mining Journal*, 36th St. & 10th Ave.,
New York, N. Y.

BRUNS, C. L., JR., School of Military Aeronautics, Mass. Institute of Technology,
Cambridge, Mass.

CALDER, NORMAN L., Sapper No. 320370, I. W. & D. Royal Engineers,
Southwick P.O., Sussex, England.

CALKINS, F. E.....Bellevue, Ariz.

- CALVERT, WILLIAM R.....706 Newhouse Bldg., Salt Lake City, Utah.
 CAMPHUIS, GEORGE A.....614 Mills Bldg., El Paso, Texas.
 CARROLL, GEORGE A.....Pacific Coast Borax Co., Ryan, Cal.
 CARSON, JOSEPH A.....Capt., A. S., S. R. C.
 CARSTENS, C. E.....27th Engineers, O. R. C.
 CHATIN, AUGUST H.....505 S. 2d East St., Salt Lake City, Utah.
 CHEYNEY, J. S.....Box 315, Charleston, W. Va.
 CLARK, H. SMITH.....Inspection Division, Ordnance Dept., U. S. Army.
 CLARK, WILL L.....Box 447, Riverside, Cal.
 COHEN, E. H. A.....250 West 82d St., New York, N. Y.
 COHEN, LOUIS.....614 Ideal Bldg., Denver, Colo.
 COMINS, WALDO H.....Capt., 41st Co., 164th Depot Brigade,
 Camp Funston, Kansas.
 COOK, EDWARD H.....Apartado 19, Culiacan, Sinaloa, Mexico.
 COONER, JOHN D.....Co. A, 30th Engineers, A. E. F., Care
 Postmaster, N. Y.
 CORTESI, EMILIO.....Volunteer, Italian Army.
 COX, HERBERT B.....Ringwood Co., 50 Church St., New York, N. Y.
 CRAMPTON, FRANK A.....Corporal, Co. C, 115th Engineers, Camp Kearney, Cal.
 DAULTON, THEODORE M., Gen'l Mgr., Placer Gold Mines Co., 208 New York Bldg.,
 Seattle, Wash.
 DAVIES, FRED A., Sgt., 419th Depot Detachment, A. E. F., Office of Chief Engineer,
 S. O. R., U. S. M., P. O. 717.
 DAVIS, LEWIS K.....Major, Engr., R. C., A. E. F., Care Postmaster, N. Y.
 DEAN, WILLIAM T., Pres., General Combustion Co., Monadnock Bldg., Chicago, Ill.
 DENMAN, HEBER.....Gen'l Mgr., Fernwood Min. Co., Clarksville, Ark.
 DENNIS, A. C., Roxana Petroleum Co. of Oklahoma, Box 930, Cheyenne, Wyo.
 DEWEY, GEORGE C.....Headquarters Co., 146th M. G. Bat., American P. O. No. 727,
 A. E. F., France.
 DICKSON, R. H.....2d Lieut., C. A. R. C., Fort MacArthur, San Pedro, Cal.
 DIESCHER, ALFRED J.....Care Henry L. Doherty & Co., 60 Wall Street,
 New York, N. Y.
 DOBSON, CHRISTOPHER G.....Co. K, 23d Engineers, A. E. F., Care Postmaster, N. Y.
 DRAPER, FRED W.....Fayville, Mass.
 DRESSER, JOHN A.....701 Eastern Townships Bank Bldg., Montreal, Canada.
 DUDLEY, BOYD, JR.....Capt., Inspection Div., Ordnance Dept.
 DU MOULIN, W. L.....Care New Cornelia Copper Co., Ajo, Ariz.
 DYE, A. V.....American Legation, Christiana, Norway.
 DYE, ROBERT E.....Supt., Teck-Hughes Gold Mines, Ltd.,
 Kirkland Lake, Ont., Canada.
 DYER, H. H.....Care Shannon Copper Co., Dewey, Ariz.
 EBERHARDT, WILLIAM G., Cia. Oriental de Minas, San Basilio Baja 3, Santiago, Cuba.
 EISENHARTER, R. C.....Resident Engr., Montana Cons. Copper Co., Basin, Mont.
 ELLIOTT, STUART R.....Major, 28th Engineers, A. E. F., Care Postmaster, N. Y.
 EMLAW, HARLAN S.....404 Franklin St., Grand Haven, Mich.
 ERDOFF, MAXWELL E.....2d Lieut., Headquarters Co., 602d Engineers,
 Camp Devens, Mass.
 FARNHAM, C. MASON.....Casilla 303, Arequipa, Peru.
 FEUST, ARTHUR.....Guanajuato Development Co., Guanajuato,
 State of Guanajuato, Mexico.
 FINLAY, JAMES R.....45 Cedar St., New York, N. Y.
 FOVARGUE, F. H.....Willoughby, Ohio.
 FRANKE, EMIL A.....Cerro de Pasco Copper Corp., Casilla 309, Lima, Peru.
 FRASER, THOMAS.....202 S. Romine St., Urbana, Ill.
 GAENSLER, GEORGE R.....Capt., 414 Squadron, A. S. S. C.
 GARRETT, S. G.....Naval Reserve Force.
 GASKILL, JAMES P., Cons. Engr.....506 Security Bldg., Los Angeles, Cal.
 GRAHAM, E. R.....Capt., 309th Engineers, Camp Zachary Taylor, Ky.
 GRANT, ULYSSES S., IV.....2d Lieut., Equipment Section, Procurement Div.,
 Army Ordnance Dept., 6th & B. Sts., Washington, D. C.
 GRAY, EDWIN F.....R. F. D. No. 2, Box 236, Seattle, Wash.
 GUGGENHEIM, HARRY F., Lieut., U. S. N. R. F., Naval Aviation Forces, A. E. F.,
 Care Postmaster, N. Y.
 HAAS, FRANK.....Cons. Engr., The Consolidation Coal Co., Fairmont, W. Va.
 HAFF, RAYMOND E. T.....E. I. du Pont de Nemours & Co., City Point, Va.
 HALL, MORTIMER L.....281 Golden Hill St., Bridgeport, Conn.

- HAMILTON, E. H. U. S. Smelting Co., Midvale, Salt Lake City, Utah.
 HAMILTON, O. ROSS Capt., Co. B, 23th Engineers, Camp Meade, Md.
 HARDER, E. C. U. S. Geological Survey, Washington, D. C.
 HARDIE, A. B. Lavino Furnace Co., Lynchburg, Va.
 HARTLEY, BURTON, 1st Lieut., Coast Artillery Reserve Corps, Fort Stevens, Ore.
 HARTLEY, GUY B. Box 272, Fairmont, W. Va.
 HEBERLEIN, C. A. Apt. 45, Nacozari, Sonora, Mexico.
 HEIZER, O. F. 901 Wheeler Ave., Reno, Nev.
 HELLER, ALFONCE H. Supt., Afterthought Copper Co., Ingot, Cal.
 HENRY, J. T. Martha Furnace, Centre Co., Pa.
 HOTCHKIN, HARRY 2d Lieut., 311th Engineers, Camp Grant, Ill.
 HOWE, R. E., Asst. Supt., Anaconda Copper Min. Co., 305 W. 7th St., Anaconda, Mont.
 HOWELL, JESSE V. Geol., Gypsy Oil Co., Box 815, Wichita Falls, Kansas.
 HOWRY, H. H. 1st Lieut., 302d Engineers, A. E. F., Care Postmaster, N. Y.
 HUNTER, HANSABURO, Met., E. H. Hunter & Co., 181 Uehonmachi, 5 Chome Higashiku, Osaka, Japan.
 HYBINETTE, VICTOR, A/S Kristiansands Nikkelfrafineringsverk, Drammensveien 38, Kristiania, Norway.
 IONIDES, S. A., Explosives Dept., Imperial Munitions Board, Ottawa, Ont., Canada.
 JOHNSON, F. A. Standard Oil Co. of New York, Wuhu, Anhwei Province, China.
 JOHNSTON FRED LUCIAN Mech. Engr. E. I. du Pont de Nemours & Co., U. S. Nashville Smokeless Powder Plant, Nashville, Tenn.
 JOHNSTON, FRED L. Capt., 434th Engineers, Camp Kearney, Cal.
 JUSSEN, EDMUND, Gen'l Mgr., The New Almaden Co., Inc., 57 Post St., San Francisco, Cal.
 KANARR, HARRY M. 805 E. Mahoning St., Punxsutawney, Pa.
 KEENAN, EDWARD T. Capt., Engrs. U. S. R., 37th, Fort Myers, Va.
 KEILLER, ALEXANDER G. Casilla 201, Oruro, Bolivia.
 KEMP, JAMES T., The International Nickel Co. of Canada, Ltd., Port Colborne, Ont., Canada.
 KENNEDY, H. DES 300 Pine St., Anaconda, Mont.
 KENNEY, HENRY S. P. O. Dersley, Transvaal, So. Africa.
 KENNEY, H. D. 1st. Lieut., 27th Engineers, Camp Meade, Md.
 KILBOURN, WILLIAM D. U. S. Metals Refining Co., East Chicago, Ind.
 KLUGESCHIED, WALTER P. 616 West 113th St., New York, N. Y.
 KNIFFIN, L. M. Mammoth Copper Min. Co., Kennett, Cal.
 KOHL, E. WILLIAM, JR. 1522 W. Lehigh Ave., Philadelphia, Pa.
 KOHLBERG, HERBERT S. 600 W. Boulevard, El Paso, Texas.
 KREBS, JOSEPH J., Battery A, 18th Field Artillery, A. E. F., Care Postmaster, N. Y.
 LANDERS, WILL H. Capt., 27th Engineers, A. E. F., Care Postmaster, N. Y.
 LAWS, EUGENE H. Northport, Wash.
 LEE, E. C., Chief Inspector, The Associated Companies, Chamber of Commerce Bldg., Pittsburgh, Pa.
 LINDHOLM, MILTON S., Sgt., Headquarters Co., 340th Field Artillery, N. A., Camp Funston, Kansas.
 LINTHICUM, J. F. 5796 McPherson Ave., St. Louis, Mo.
 LISBOA, M. A. R. Caixa postal 829, Rio de Janeiro, Brasil, S. A.
 LOO, PANG C. Care Miss M. A. Conling, 4 Edinburgh Road, Shanghai, China.
 MCFADDEN, G. C. Care Illinois Athletic Club, Chicago, Ill.
 MCINTYRE, JOHN E. Box 63, Nogales, Ariz.
 MACKENZIE, J. D., Lieut., 185th Cape Breton Highlanders, C. E. F., Army P. O., London, England.
 MACKILLIGIN, A. M. Capt., British Army.
 MARCH, ALBERT T., Burma Mines Ltd., Namtu, Northern Shan States, Burma, India.
 MARQUARDT, ERNEST 2d Lieut., 602d Engineers, Camp Devens, Mass.
 MARSH, ROBERT JR. Capt., Aviation Section, P. O. 702, A. E. F., France.
 MARSHALL, STUART B., Care Miss Mary S. Porter, 110 Mountain Ave., S. W., Roanoke, Va.
 MARTIN, ROBERT L., JR., Efficiency Engr., Northampton Coke Plant, Bethlehem Steel Co., Northampton, Pa.
 MATTESON, W. G. 314 Texas State Bank Bldg., Ft. Worth, Texas.
 MEANS, ALAN H. Headquarters Co., 304th Field Artillery, N. A., 77th Div.
 MEGRAW, H. A. Production Engineering Dept., U. S. Army, Signal Corps, 624 Lindsey Bldg., Dayton, O.
 MICKEL, ROBERT ELI 2d Lieut., E. O. R. S., L. of C., A. E. F., France.

- MONTZ, HARRY WILLIAM.....Div. Engr., Lehigh Valley Coal Co., Hazleton, Pa.
 MUIR, J. MALCOLM.....Gen'l Mgr., Metallurgical & Chemical Engineering,
 10th Ave. & 36th St., New York, N. Y.
- MUSSIGBROD, LUDWIG S.....Garnet, Mont.
 NEWELL, G. S.....742 E. Pennsylvania Ave., San Antonio, Texas.
 OLIVER, EARL.....Roxana Petroleum Co., Tulsa, Okla.
 OLWAGE, M. F.....Box 222, Oakland, Cal.
 ORDONEZ, EZEQUIEL.....2a General Prim, 43, Mexico City, Mexico.
 OSBORN, F. W.....Apt. 66, 672 St. Nicholas Ave., New York, N. Y.
 PATTERSON, C. T.....Met., Standard Chemical Co., 213 Belmont St.,
 Cannonsburg, Pa.
- PAUL, RUSSELL B., Gen'l Mine Supt., The Empire Zinc Co., 703 Symes Bldg.,
 Denver, Colo.
- PEARCE, JACKSON A.....1620 Orford St., Berkeley, Cal.
 PEARL, HOLMAN I.....Mines Efficiency Co., 709 Alworth Bldg., Duluth, Minn.
 PENHALE, H. J. D.....Casilla 56, La Paz, Bolivia, S. A.
 PHILLIPS, D. McN., 1st. Lieut., Signal Reserve Corps, Aviation Section,
 Ellington Field, Texas.
- PIGOTT, CURTIS.....St. Joseph Lead Co., Herculaneum, Mo.
 PLACE, RICHARD G.....Chem., Ray Cons. Copper Co., Box 734, Hayden, Ariz.
 POTTER, WINFIELD S.....Alloy Steel Forging Co., 530 Fourth Ave., Pittsburgh, Pa.
 REYNOLDS, GEORGE B.....1 Ellersdale Road, Hampstead, London, N. W. 3, England.
 REYNOLDS, H. I.....3422 Anna St., East San Diego, Cal.
 ROBERTSON, JASPER T.....Afterthought Copper Co., Ingot, Cal.
 RODGERS, ALAN M.....Lieut., 312th Engineers, Camp Pike, Ark.
 ROOT, JOHN A., Capt., Ordnance Reserve Corps, Peters Cartridge Co., Kings Mills,
 Warren Co., O.
- ROPER, GEORGE JR.....Lieut., Royal Flying Corps.
 ROYCE, WARD.....Capt., Co. B, 27th Engineers, Camp Meade, Md.
 RUGGLES, GUY H.....Inspiration Cons. Copper Co., Miami, Ariz.
 RYPINSKI, J. E.....Utah Metal & Tunnel Co., Bingham Canyon, Utah.
 ST. CLAIR, STUART.....Fraternity Bldg., Winchester, Ky.
 SANFORD, H. E.....Co. C, 4th Engineers, Camp Green, Charlotte, N. C.
 SARGENT, WILLIAM D.....National State Bank Bldg., Newark, N. J.
 SCAIFE, HAZEL L.....Capt., Signal Reserve Corps, Aviation Section.
 SCHINBECKLER, OSCAR T.....Cunningham, Kans.
 SCHLERETH, C. Q., Compania Minera de Penoles, S. A., Ojuela, Mapimi,
 Durango, Mexico.
- SCHULTZ, C. I.....1303 Linden Ave., Long Beach, Cal.
 SCHUMACHER, A. J.....Weiser, Ida.
 SCOTT, H. KILBURN, Director of Home Ore Supplies, Gold Street Chambers,
 Kettering, Northamptonshire, England.
- SCOTT, JOHN T.....1st Lieut., 335th Infantry, N. A., Camp Zachary Taylor, Ky.
 SEIP, ROBERT H.....Engr., Witherbee Sherman & Co., Inc., Mineville, N. Y.
 SHARPLESS, F. F.....17 Madison Ave., New York, N. Y.
 SMITH, ELWYN L.....The University of Minnesota, Minneapolis, Minn.
 SOPER, ELLIS.....2110 Hayes St., Nashville, Tenn.
 SPIERS, JAMES.....U. S. R., A. E. F., France.
 STANLEY, FRANK A.....157 Ronado Ave., Piedmont, Oakland, Cal.
 STRIDLE, EDWARD, 1st Lieut., Co. A, 30th Engineers, A. E. F., Care Postmaster, N. Y.
 STEVENS, BLAMEY.....Nogales, Ariz.
 STEWART, LEIGHTON, Lieut., Canadian Engineers, Engineers Training Depot,
 St. John's, Quebec, Canada.
- STOUT, V. A., Mgr. Branch Office, Hardinge Conical Mill Co., Newhouse Bldg.,
 Salt Lake City, Utah.
- SULLIVAN, CLARKE.....Capt., Engr. Officers' Reserve Corps.
 SULLY, KENNETH M.....Corp., Co. C, 29th Engineers, Camp Devens, Mass.
 TARANTOUS, RICHARD.....Lieut., 8th Mountain Engineers, El Paso, Texas.
 TAYLOR, HENRY B., 2d Lieut., Signal Reserve Corps, Aviation Section,
 Scott Field, Belleville, Ill.
- THOMAS, J. ELMER.....Elmhurst, Ill.
 THOMPSON, LESTER S.....Co. C, 29th Engineers, Camp Devens, Mass.
 TICHBORNE, HERBERT M., 88th Aviation Section, Signal Corps,
 A. E. F., Care Postmaster, N. Y.
- TREICHLER, H. E.....Hotel Great Northern, West 57th St., New York, N. Y.

VAIL, RICHARD H., Requirements Section, Control Bureau,
 Ordnance Dept., Washington, D. C.
 VAN VALKENBURGH, R. D.....607 Decatur St., Watkins, N. Y.
 VAN WAGENEN, HUGH R.....1225 Foster Bldg., Denver, Colo.
 VORHEES, FREDERICK A.....Daggett, Cal.
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NECROLOGY

The deaths of the following members were reported to the Secretary's office during the period Mar. 10, 1918, to Apr. 10, 1918.

Date of Election.	Name.	Date of Death.
1917	Adams, Lloyd D.....	Mar. 18, 1918.
1902	Bowie, Alexander.....	Feb. 10, 1917.
1915	Clarke, James P.....	Oct. 28, 1917.
1914	Cochran, William A.....	July 17, 1917.
1914	Evans, A. W. (Killed in action).....	1917.
1902	deGennes, A. A.....	Sept. 1916.
1904	Hawkins, John T.....	Jan. 26, 1918.
1888	Henrich, Carl.....	Dec. 19, 1917.
1888	Kondo, R.....	Nov. 6, 1917.
1915	Lewis, C. F.....	May 5, 1917.
1906	Lucas, John R.....	Mar. 1917.
1890	Malcolmson, J. W.....	Dec. 26, 1917.
1901	Noon, Thomas F.....	Mar. 2, 1918.
1876	Schwarz, Theodore E.....	Oct. 1, 1917.

BIOGRAPHICAL NOTICES

FRED TURRELL GREENE

Fred Turrell Greene was born in Brooklyn, N. Y., Nov. 22, 1872. His father, William A. Greene, was born in Providence, R. I., and his mother, Angenora Semlear, was born in Brooklyn, N. Y. Fred's early school days were spent in Boston, whence his father moved to Canada in 1882. Attending first the Collegiate Institute in Toronto, then the High School at Berlin (now Kitchener), Ontario, where he graduated, Fred progressed to the Toronto University and the Michigan College of Mines, at Houghton, where he graduated in 1897.

He secured employment almost immediately at Butte with the engineering force of the Boston & Montana Consolidated Silver Mining Co., under Chas. S. Batterman. In 1899 he went to Rossland, B. C., where he spent more than a year as mining engineer and assistant superintendent of the War Eagle Consolidated Mining and Development Co. and the Center Star Mining Company Ltd. Returning to Butte in 1900, he acted as assistant geologist for the Anaconda Copper Mining Co. until 1906, when he filled a similar position in St. Paul with the Great Northern Railway for about two years. From 1908 until his tragic death on Christmas day, 1917, his headquarters were in Butte, where he enjoyed an excellent reputation as consulting mining engineer, with a rapidly widening circle of clients. During the past four years he had been consulting engineer for the Elm Orlu and other mines controlled by Hon. W. A. Clark, and was in charge of underground developments and law-suit preparations for the celebrated apex case between the Elm Orlu and the Butte & Superior companies. At the time of his death he was in charge of similar work for the Utah Metals Co., in connection with their mines at Bingham, Utah. He was also for some years active in the Coeur d'Alenes, as consulting geologist for the Federal and other companies there, and was considered an authority on this as well as the Butte district.

Mr. Greene was unmarried, and is survived by his parents, a younger brother, who is in the army, and one sister, Mrs. James A. Hatch, of New York.

Some of the most important and valuable ideas regarding the nature and origin of copper ores have originated in Butte, since that district is not only one of the greatest examples of mineralization known in any land, but has gone through a long course of mining litigation, and was one of the first to be studied intensively by geologists. In connection with the early investigations, as well as with the most recent in that camp, Mr. Greene played an important part. His conscientious devotion to his duties and his intelligent handling of the problems presented for solution sufficiently explain the esteem in which he was held by his employers and his professional associates.

Firmly established in his profession, his career seemed assured. For years an active and loyal member of the American Institute of Mining Engineers, ready at all times to work in its interests, he was a valued member of its committee on mining law and contributed to its *Transactions*¹ a valuable paper on the peculiarities of apex law as adjudicated

¹ *Trans.* (1915), 52, 555.

in the Coeur d'Alenes. Among his associates his reputation as an engineer is safe, and for his qualities as a man the number and character of his friends are ample testimonial.

HENRY KEHOE

Henry Kehoe died at Los Angeles, Cal., Feb. 6, 1918. He had a long experience in mining in the Western United States, Canada, and Mexico, and had been at different times during the past 25 years representative for several American and Canadian companies. He was in Arizona and Northern Sonora in the early eighties, later in the Black Hills, Cripple Creek, and Rosslund. He made Spokane his home for many years, removing to Arizona and Southern California in 1915.

ROKUSABURO KONDO

Dr. Rokusaburo Kondo was born in 1857 at Yedo (now Tokyo), Japan. It was not then yet remote from the time when the doors of the Empire had been knocked open by Commodore Perry. No wonder that in the days of his youth the value of Western learning was not fully known to the public, and university education was confined chiefly to the young men sent to the capital by feudal lords. It is remarkable, therefore, that Mr. Kondo, without any such encouragement, entered the Imperial College of Engineering instituted and placed under the presidency of Dr. Henry Dyer. He took the course of mining there and, finishing it in 1880, entered the public service at a copper mine in north Japan, then owned and worked by the Government.

After about five years, the mine was transferred into the hands of the late Mr. Ichibei Furukawa, in whose interest the young engineer continued his labors. The new owner, afterward known as the Copper King of the Empire, was a born captain of industry. Kondo, finding an ideal master in him, and enjoying his full confidence, threw his whole energy into the work. He went abroad in 1888 and travelled extensively in America and Europe, closely studying the mining industry of both continents. At this period, he became a member of the American Institute of Mining Engineers. On his return in the succeeding year, he was entrusted with charge of all engineering matters in the mines and works owned by Mr. Furukawa's firm, thus enjoying ample opportunity to put in practice his newly acquired knowledge. In this capacity he did much to introduce new inventions to the mines with which he was connected. In 1897 he was appointed General Manager of the Ashio copper mines, the largest in Japan. There again he accomplished many improvements of importance; but the work particularly worth mentioning is the construction in 1897 of works to remedy water-pollution.

For some years previous, people farming along a river which flowed by the mines had experienced bad crops of rice, and, with or without reason, attributed this evil to the pollution of the river by poisonous water coming from the mines. Protesting vehemently against the copper king, they formed a mob which, coming up to the capital, applied to the Government for immediate closure of the work. The authorities listened to their cry; and the result was an order for the mine owner to construct a series of works to prevent the alleged water-pollution. The time allowed was unreasonably short, and it seemed almost impossible to complete the construction in time. But the manager worked most strenuously at the

task and finished it soon enough, thus saving the mines from a suspension of work which would have been unavoidable otherwise.

In 1903 he was appointed director, and in 1913 chief director, of Furukawa & Co. The highly prosperous condition of this company at the time of his death may be regarded as a testimony of his own success. He was also very earnest in trying to advance the mining interests of the country in general. He received the degree of Doctor of Engineering in 1915 and in the same year, on the occasion of the Coronation, H. M. the Emperor conferred upon him the Jugoi (Junior Fifth Grade of the Imperial Court Rank)—an honor very sparingly extended to subjects not connected with the Government; Mr. T. Furukawa, successor to Mr. I. Furukawa and now president of the company, was created Baron on the same occasion, in recognition by His Majesty of his services to the mining industry of the Empire.

Dr. Kondo died from an illness at his residence in Tokyo on Nov. 6, 1917. His somewhat sudden passing away was as much lamented by the mining world at large as by his friends, as was evinced in the addresses read on the occasion of his funeral by Mr. T. Wada, Dr. W. Watanabe, Dr. M. Otagawa and others representing several institutions and associations. He was survived by Mrs. Hiro Kondo and succeeded by Mr. Shin-ichi Kondo, his only son. His two daughters are married, the elder to Dr. R. Funabashi, Professor of Engineering in the Tokyo Imperial University, the younger to Mr. M. Kibe, who formerly held office under the Government and now serves in Furukawa & Co. M. OTAGAWA.

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A detachable form is here offered for the convenience of members in proposing candidates for admission to the Institute. On the next page is an extract from Article II of the Constitution, as amended in February, 1918, stating the requirements for admission as Member, Associate Member, or Junior Associate. Further particulars as to manner of conducting elections, and as to initiation fees and annual dues, will be found in the back of the Year book, distributed in March.

IMPORTANT TECHNICAL PAPERS IN THIS ISSUE

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Man Power.	By J. Parke Channing
Carbocoal	By C. T. Malcolmson
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Theory of Volcanic Origin of Salt Domes	By E. L. de Golyer
Oil in Southern Tamaulipas	By Ezequiel Ordonez

**Discussions at the New York Meeting, February, 1918,
of papers relating to the following subjects:**

Coal Situation of the World.
Anthracite Briquetting.
Valuation of Oil Lands.
Grain-size Inheritance in Iron and Steel.
Crippled Soldier in Industry.
Operations of the Russell Sage Foundation.

REQUIREMENTS FOR MEMBERSHIP

Attention is called to the following extract from Article II of the Constitution, as amended in February, 1918.

A person to be eligible for election or transfer into the class of Members must be at least 27 years of age and must have had at least six years' employment in the practice of engineering, mining, geology, metallurgy or chemistry, during at least three years of which he must have held positions of responsibility in one or more of these fields.

Graduation from the scientific course of a college, approved by the Committee on Membership, shall be considered equivalent to two years' employment, as required in the previous sentence.

Employment as a teacher of engineering, mining, geology, metallurgy or chemistry, if in direct charge, may be considered a position of responsibility as specified in the second paragraph.

Persons employed in research or any scientific literary work or in teaching in the scientific departments of colleges, approved by the Committee on Membership, who at the same time are engaged in consulting or in the active practice of mining, geology, or metallurgy, shall be entitled to consider the time so spent in active practice as equivalent to an equal length of time of employment in positions of responsibility, provided the work done or the positions held seem to the Committee on Membership to warrant the equivalency.

The requirement of three years' employment in positions of responsibility may be waived by the Committee on Membership in the case of persons who have done notable original work in mining, geology, or metallurgy, or have won distinction by research or investigations in one or more of these subjects. By investigation or research is understood laboratory experimentation as distinct from investigations in literature or compilations of the work of others.

A person eligible for election or transfer into the class of Associates shall be one, who, in the opinion of the Committee on Membership and the Board of Directors, is suitable for such election or transfer by reason of his interest in or connection with mining, geology, metallurgy, or chemistry.

Junior Associates shall comprise all students in good standing in engineering schools, who have not taken their degrees and are nominated by at least three members, two of whom must be their instructors. A Junior Associate may remain such not longer than five years after leaving the engineering school, at the end of which period his qualifications to become a Member or Associate must be passed upon by the Committee on Membership. If elected he shall pay at that time the entrance fee and dues of a Member or Associate.

In case there is any question as to the classification of a candidate the Committee on Membership may require from him any evidence he desires to present and the decision of the Committee as to the proper status shall be final.

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[illegible]

I agree, if elected, to accept election within four months, and to abide by the Constitution and By-Laws

Dated _____ 191

DISCUSSION OF THIS PAPER IS INVITED. It should preferably be presented in person at the Colorado meeting, September, 1918, when an abstract of the paper will be read. If this is impossible, then discussion in writing may be sent to the Editor, American Institute of Mining Engineers, 29 West 39th Street, New York, N. Y., for presentation by the Secretary or other representative of its author. Unless special arrangement is made, the discussion of this paper will close Oct. 1, 1918. Any discussion offered thereafter should preferably be in the form of a new paper.

Man Power*

BY J. PARKE CHANNING,† E. M., M. S., NEW YORK, N. Y.

(Colorado Meeting, September, 1918)

WE are accustomed to think that we are efficient in the United States, particularly with respect to such things as mining and manufacturing. The conduct of the war has demanded in England and in France a complete readjustment of manufacturing methods and plans, and today England is probably as efficient a country as there is in the world, not even excepting Germany. This is all the more remarkable because it has been notorious for years that England has been inefficient in her manufacturing and the country has been flooded with things "Made in Germany." Today England is almost a socialistic community and the State is doing almost everything. England is now in such a position that practically everyone in the country is engaged in industry necessary for the conduct of the war, and this has been accomplished by increasing the efficiency both of her tools and of her man power.

In the United States we certainly have been efficient so far as machines and perhaps so far as methods have been concerned, but we have not been efficient in the utilization of our man power. Before the war, our labor was undoubtedly far more efficient than that of England, but it certainly was not so highly efficient as it should have been, and the problem that confronts us today, and will all the more confront us after the war, is to make our man power efficient. England has had a taste of what you may call State Socialism, and her laboring men are not going to be content to return to the old order of things. There is one feature of the labor problem in England which has permitted her to reach this condition of state socialism with comparative rapidity; this is that practically all of her laborers are English; she has little or no foreign population. While an Englishman may be a strong union man and ready to fight his employer tooth and nail, at heart he is still a British subject, and when his country was in danger he rose to the occasion.

In the United States we have such an admixture of unassimilated foreigners that the problem is more difficult, and as yet we have not been brought to that point of stress which has arrived in England. But if

* Presented at a meeting of the Boston Section, Mar. 15, 1918.

† Vice Pres., Miami Copper Co.

we are to carry the war to a successful conclusion, and if we are to increase our efficiency after the war, we must introduce methods which will Americanize these foreigners and give them our own point of view. We have been called the melting pot, but it is a question whether even our melting is efficient, and whether at the top of the crucible there does not accumulate too much dross and at the bottom not enough clear alloy.

I wonder if any large number in this country have read the so-called reconstruction programme of the British labor party. It will, of course, be subject to a great many modifications before it is adopted by the party, and no doubt still further and greater modifications will be made before any or all of it is accomplished. It is very largely socialistic and has for its basis four principles or pillars, as they choose to call them, of the house which they hope to erect. These four pillars are:

1. The universal enforcement of the national minimum.
2. The democratic control of industry.
3. The revolution in national finance.
4. Use of surplus wealth for the common good.

If these four demands are carried out, then surely England will be a socialistic state.

I am not prepared to say how much of this programme can, or will, be carried out, but it shows the trend of thought of the laboring man in England. He has seen his wages increased so as to keep pace with the growing cost of living, he has seen the profiteer discouraged, and he is more than ever convinced that in the past he has not been getting his fair share of the product of his toil; and, I believe, at the same time he is realizing that undoubtedly in the past he has not done his proper share in increasing the wealth of the country. Nor can he be blamed for this, because, seeing large fortunes grow up before his eyes, while he gets but a small proportion of it, the incentive to increased efficiency has not been great. He realizes that when the war is over, unless the greatest care is used in the reorganization of the regular industries, there will be an immense amount of unemployment; that this, if unchecked or uncared for, will result in an over supply of labor, and, if the old standard is maintained, a corresponding diminution in wages. This he feels should not be; hence his insistence of the first principle of a minimum wage. And the minimum wage that he asks for is certainly not a high one, being 30s. or, we will say, \$7.50 a week.

In demanding democratic control of industry he has observed such good results attained in war work that he sees no reason why this control of industry should not be just as efficient under after-war conditions.

In the third pillar, the revolution in national finance, he demands that taxation shall be so adjusted that it will yield the necessary revenue to the Government without encroaching upon the prescribed national

minimum standard of life of any family whatsoever; without hampering production or discouraging any useful personal effort, and with the nearest approximation to equality of sacrifice. Apparently he is not a protectionist and repudiates all proposals for a protective tariff; however, this may be disguised. In this point they agree with Mr. Courtenay de Kalb, a prominent mining engineer, who, in the December, 1917, number of the *Atlantic Monthly*, has a most excellent article on the Formula for Peace, in which he states that, if after the war we can have an industrial world in which there are no protective tariffs and no subsidies, in which every nation is engaged in producing those articles for which it is best adapted, that then there will be less incentive for war.

The fourth pillar of the English laborite is that the surplus wealth shall be used for the common good. They say that we have allowed the riches of our mines, the rental value of the land superior to the margin of cultivation, the extra profits of the fortunate capitalists, and even the material outcome of scientific discoveries, to be absorbed by individual profiteers, and he demands that in the future a large proportion of this surplus shall be applied to the common good.

You must realize that the English labor party is not like the Bolsheviks of Russia. It is not carried away with the beliefs of Lenine and Trotsky, that the proletariat are the men to manage the country. The English laborer frankly realizes the importance of brains and education, and admits that the highest success of the country cannot be obtained without the aid of those who plan, and manage, and invent, nor would he object to allowing these men to get their fair share of the profits. Evidently the class against which his programme is aimed is comprised of those more or less sharp and shrewd men who, without anything more than commercial ability, of themselves reap the advantages of the brains and muscles of others.

It is not for me, nor am I a sufficient student of economics, to pass upon this programme. It has certain merits, and I am calling it to your attention only that you may see that just this same thing is liable to come up in the United States. And the trouble will be that the pendulum will very likely swing too far if the employer class in the United States does not give more attention to the laborer and see that his condition is improved. You, as engineers, are in the position to act as the instruments for carrying out this necessary work. Whether it be in a mine or a manufacturing plant, I believe I can say that today a large proportion of the managers and executives are engineers, and the proportion is constantly increasing.

The question to be clearly faced is, are we properly trained to bring about this improvement in our social condition, to improve the living conditions of our laborers and at the same time to improve their efficiency? I fear that a great many of us are not. We may be good technical men

but we are not sociologists nor psychologists. We understand production of kilowatt-hours from coal or from water power, we understand the machine by which it is utilized, but we do not understand the machine which produces our man power.

I recently attended a conference at Columbia University, at which the question of giving the engineering students a course in human engineering was discussed, and I came away with the idea that the authorities were beginning to realize that this was of paramount importance and that this training must be given the engineering student before he can be turned out as a man capable of eventually holding a high executive position. Many of the students have the ambition to hold high positions, but at the same time, in the most naïve manner, announce that they have no desire to have anything to do with the working men themselves. In my opinion, there never was a time when it was so necessary to impress upon engineers and engineering students the importance of this human side of engineering.

I wonder how many of you can tell me what trade unionism is—you who have had to deal with unions and have had strikes? The fact is that none of you can tell what trade unionism is because trade unionism is not an entity but a term of broad generalization covering a great many distinct aspects of the labor problem. Some of you who, perhaps, are railroad superintendents, whose knowledge of trade unionism is based upon your contact with the Brotherhood of Locomotive Engineers, would give one definition; others, who have been managing a mine in the Rocky Mountains, whose contact has been with the Western Federation of Miners, would give another definition. Specifically, each of you would be right from his own point of view, but neither of the definitions would cover trade unionism as a whole. A few weeks ago I might have been rash enough to attempt a definition, but in the meantime I have read Professor Hoxie's work on "Trade Unionism in the United States," and my ideas on the subject have been much clarified. I would advise every one who has anything to do with trade unionism to get this work and not merely read it but study it as you would study a book on electric motors to find the difference between an induction motor and a synchronous motor, between one that was simply wound and one that was compound wound.

You will find that trade unionism can be classified under two broad general heads, one based on structural varieties, and one on functional varieties. As Professor Hoxie points out, there are four divisions under each head and any one of the structural varieties may function in any one of four different ways. You will learn that while, to you, decreased output on the part of the laborer seems inexcusable, yet, for him, it has an intense and immediate value. You will find the reason why he insists that the good and the poor workman shall each turn out

the same amount of product every day, and you will find that he has most excellent reasons for this, reasons that probably never entered your head. You will learn why the locomotive engineers of the United States can have one strong central national union, and why this is impossible with the men who dig ditches. You will discover why the Knights of Labor movement failed and why the American Federation of Labor has succeeded. There is one basic and most important factor which you must realize, namely, that, talk as you may, the interest of the laborer and the interest of the employer are diametrically opposed, just as the interest of the buyer and the interest of the seller are opposed, that from the very nature of things they can never be identical, and that the best that can ever be reached is a compromise. And who is better qualified to bring about this compromise than the well trained engineering manager who, with his broad knowledge and experience with both capitalist and laborer, is enabled to act as an arbiter or a judge and arrive at a decision at least fairly equitable.

It is the engineers of this country who are in a position to solve the labor problem, or at least to produce a solution as nearly ideal as possible. It is you who are to convince the employer that, in the long run, he is going to be better off by increasing the wages of his men, reducing their hours of work, and improving their living conditions. It is you who must convince the laborer that it is to his interest to work as efficiently as he can and to produce as large an output as is possible. You will have to do this by education. It is difficult to convince a laborer that by increasing his efficiency and his output he helps himself, because he only looks to immediate results. But do not be carried away with the idea that because the laboring man upholds an economic fallacy that you cannot convince him of his error.

About 10 years ago I started to develop a low-grade copper mine in Arizona. As mine superintendent I had Mr. N. Oliver Lawton, a member of this Institute, whose experience at Lake Superior has made him familiar with what is known as the one-man air drill. This is a light machine weighing about 125 lb., which can be readily set up and operated by one man. We started to use these in Arizona where, before, nothing but the larger and heavier machine, requiring two men, was in use. There was an immediate opposition from the men and we were accused of trying to throw half the normal number of miners out of work. Whenever I went through the mine I took the opportunity to tell the men that this orebody, up to that time, had not been considered ore, that it was rock, and that nobody thought it was worth exploiting; that, far from throwing one man out of work, we were giving two men jobs, that if two men had to work on a drill the cost of mining would be so high that the material would not be ore, but that if we gave each man a drill and put him to work in a separate drift, then the rock would become

ore, that these men would have employment and that a new industry would be started. About three months of this propaganda convinced the men of the truth of our claim, and in a short time it would have been impossible to get the men to go back to the old two-man drill because each man now felt that he stood on his own feet and got credit for the whole distance he drifted. This is only one example, but it indicates what can be done by education. The old-time manager or old-time superintendent would simply have said, take the job or leave it; but this is not the attitude for the modern engineer.

The assertion is made in Washington that it is difficult to get executives for war work, particularly executives who understand the handling of man power. I am told that some of the new plants for war industries have been most carefully laid out, taking into consideration the routes by which material is to arrive at the plant, its progress through the works, and its method of removal, the supply of water, coal, and other material, but in a great many cases no thought has been given to the handling of the men, to their housing, or, if they are to be brought from an adjacent town, of the method of transporting them to and from the plant. These have been left to a hit or miss adjustment after the plant was up.

For several years the industrial department of the Y. M. C. A. has had a secretary who has devoted himself almost entirely to impressing upon the engineering schools the necessity for having a course in human engineering, and in 1916, under their auspices, the first convention to discuss the human side of engineering was held in Ohio. They lay great stress upon the advantages that would accrue to engineering students if they had an insight into the mental operations of the laboring man, and this has been fostered by getting the engineering students to volunteer one or more hours of the week for instruction to laborers employed in adjacent plants. This instruction is either in the English language, in citizenship, or in athletics. A man who has volunteered for this work for a year or more, on going out into active life is a much more capable foreman than one who graduates from an engineering school and meets his first laborer somewhere on his new job.

Lately the National Americanization Committee of New York, of which Mr. Frank Trumbull, of the Chesapeake & Ohio Railroad, is Chairman, has been conducting similar propaganda, sending to the various educational institutions of the country a proposed basis of a course on industrial engineering. The Committee realized the importance of this in preparing engineering graduates for the problem of properly utilizing the man power of the country. This proposed course goes into the scope of industrial engineering, describes the problem and the field; it takes up the question of the engineering insight of the work in reference to plant building, its location, and the fundamental considerations in its construction; it takes up the management and division of the

work, the analysis of the costs, and the machinery, and the materials, and the efficiency methods. It goes into the question of employment, management, and the methods for hiring, promoting, and transferring men. It also takes up industrial welfare with the various incentives to the workman and the provisions for his health and recreation, and for the vocational training of either himself or his children. It also gives instruction in that branch which is so often neglected, and that is, conditions outside of the plant, the housing of the men, the planning of the town, and the health and recreation and education of their families. It takes up the problem of Americanization and what shall be done to make our melting pot efficient, without dross, and finally it gives him instruction as to what has been done and what should be done in legislation.¹

You engineers who are college graduates should use your influence to see that courses in human engineering are introduced in your Alma Maters, if they are not already there.

Do you mining engineers realize that your training and your experience, touching as it does on all branches of engineering, fits you better for broad and important work than those in almost any other profession? How many of you have been under the necessity of developing a large mining property in some out of the way place, when everything came before you and nothing could be left to chance, where you had to see that your own town was built and provided with water works and sewers, lighting plant, and schools? You had to develop a property in a place where nothing existed and you did not have a well organized community to fall back upon with all these adjuncts provided. Only recently one of my former superintendents came into the office to tell me that he had given up a \$12,000 a year position to take one with the Government for \$3600. He did not hunt this Government job, it came after him. They asked him to go on to Washington and take a job in the Ordnance Department. They said that they had found that a mining engineer has had such varied experience, and has driven so little in ruts, that at a minute's notice he can jump from 6-in. projectiles to bailed hay.

¹ See *Bulletin* No. 132, December, 1917, p. xlii.

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Carbocoal

BY CHARLES T. MALCOLMSON,* CHICAGO, ILL.

(Colorado Meeting, September, 1918)

AN elaborate series of experiments has been conducted during the past three years at Irvington, N. J., which has resulted in the perfection of a process for the manufacture of smokeless fuel from high-volatile coals, and for the recovery and refinement of the coal-tar products derived therefrom. These experiments have been financed by Messrs. Blair & Co., of New York, and were conducted under the direction of Charles H. Smith, a member of this Institute, and the inventor of the process.

The low-temperature distillation of coal has interested investigators for many years. Sporadic attempts have been made to solve the mechanical problems, but until the Smith process was developed, they were not carried to conclusions of economic value. The present coal shortage and the increasing demand for smokeless fuels make this subject one of timely interest.

DESCRIPTION OF PLANT

The following equipment was installed and operated during the experimental period: Four horizontal and two vertical units of commercial size for the low-temperature distillation of the coal; two vertical, two horizontal, and two inclined benches for distillation of the briquets at medium and higher temperatures; presses and auxiliary equipment necessary for making briquets; and a complete byproduct recovery and tar-refining plant. This commercial equipment is provided with gas and electric meters, pyrometers and other apparatus for recording accurately the results of all experiments.

There is, in addition to the commercial equipment, a complete chemical laboratory with distillation and recovery apparatus, including facilities for refining and cracking the tar and measuring the yields and calorific value of the gas. This apparatus makes possible a study on a small scale, of the various problems involved in the process.

* President, Malcolmson Briquet Engineering Co.

DESCRIPTION OF PROCESS

Mr. Smith's experiments have resulted in the production on a commercial scale of:

1. A fuel, called Carbocoal, which, for convenience in handling, is prepared in briquet form.
2. A yield of tar more than double that obtained in the ordinary by-product coking process.
3. Ammonium sulphate in excess of that normally recovered in the ordinary byproduct coking process.
4. Gas, in amount approximately 9000 cu. ft. per ton of coal carbonized, which is at present used in the process.

The essential features of the Smith process are the two distillations carried on at different temperatures, first of the raw coal and second of the raw briquets. The raw coal, after being crushed, is distilled at a relatively low temperature, 850° to 900° F., and the volatile contents are thereby reduced to the desired point. The result of this first distillation is a large yield of gas and tar, and a product rich in carbon, termed semi-carbocoal. The semi-carbocoal is next mixed with a certain proportion of pitch obtained from the tar produced in the process, and this mixture is briquetted. The briquets are then subjected to an additional distillation at a higher temperature, approximately 1800° F., resulting in the production of carbocoal, the recovery of additional tar and gas, and a substantial yield of ammonium sulphate.

The characteristic feature of the primary distillation is that it is continuous and that the coal is constantly agitated and mixed during the entire operation. This is accomplished by a twin set of paddles which also advance the charge through the retort. By this means, all portions of the charge are uniformly distilled, and by controlling the speed at which the charge moves through the retort, the distillation may be arrested at any desired stage. As only a partial carbonization is permitted in the primary distillation, the hard metallic cells characteristic of coke are avoided. The period of distillation is 1 to 2 hr., and the continuous retort has a carbonizing capacity of one ton of coal per hour.

In the subsequent distillation of the briquets, all evidence of the pitch as a separate ingredient disappears. There is a marked shrinkage in the volume of the briquet, with a corresponding increase in density, but no distortion of its shape. This distillation requires 4 to 5 hr., and is performed in an inclined, self-charging and self-discharging bench.

The carbocoal represents more than 72 per cent. of the weight of the raw coal, the exact percentage depending upon the volatile content of the latter.

CHARACTERISTICS OF CARBOCOAL

Carbocoal is dense, dustless, clean, uniform in size and quality, and can be readily handled and transported long distances without disintegration. It is grayish black in color, slightly resembling coke, but its density more nearly approaches that of anthracite coal. It is manufactured in briquet form and can be made in any size, from 1 oz. to 5 oz. The larger sizes are better suited to locomotive purposes, and the smaller sizes for domestic use.

Heretofore, devolatilized fuels, such as coke, have not attained the high rates of combustion desired for locomotive, marine and general steam purposes; and their greater displacement has operated against their general use where transportation cost or stowage space has been an important factor. Carbocoal overcomes these objections. It is actually a relatively soft but tough form of carbon, readily attacked by oxygen in combustion; and for this reason, requires much less draft than other high-carbon fuel.

CARBOCOAL FOR STEAM PURPOSES

Carbocoal has been tested by the Long Island Railroad; by the Pennsylvania Railroad at its testing plant at Altoona; by the Carolina, Clinchfield & Ohio Railroad; and by the United States Navy.

These tests have demonstrated that the fuel is smokeless; that it will evaporate from 8.5 lb. of water at a combustion rate of 100 lb. per square foot of grate surface per hour, to 12.8 lb. of water at a combustion rate of 27 lb. per square foot of grate surface per hour, from and at 212° F. per pound of fuel fired; and that it requires no greater draft than bituminous coal. A maximum combustion rate of 166 lb. per square foot of grate surface per hour has been reached for a short period.

Carbocoal has been found particularly suitable for the following purposes:

1. Marine and locomotive service, where limited grate area and restricted boiler capacity demand efficient fuel; where smoke is objectionable or dangerous, as in the case of ships in time of war.
2. Stationary boilers, where smoke pollution of the air is offensive and dangerous to health.
3. Domestic uses, including furnaces, stoves, ranges and open grates, where cleanliness is a desirable factor.
4. Kilns, drying and roasting ovens, and all purposes where an intense and uniform heat is desired.
5. In metallurgical furnaces, as a substitute for coke.
6. Gas producers.

CARBOCOAL AS A DOMESTIC FUEL

Carbocoal has been subjected to practical tests in household use for over 1 year. It fulfils all requirements of a domestic fuel. It can be burned satisfactorily without change of furnace or grates, responding readily to changes in draft. The uniformity of combustion, absence of fines, even distribution of ash, and absence of clinker as compared with the coal from which it is made, are additional characteristics in favor of this fuel.

Tests have demonstrated that carbocoal can be banked satisfactorily over night, requiring no more attention, and with no greater consumption, than anthracite.

COMPARISON WITH OTHER BRIQUETS

Carbocoal is compressed into briquet form to obtain maximum density, to minimize transportation costs and the losses incident to handling; and to secure the efficiency of combustion resulting from uniformity of size.

Briquets of bituminous and anthracite coals have been manufactured for many years. Such briquets are made from the smaller sizes or screenings of coal, with the addition of a binder, such as coal-tar pitch. In carbocoal, however, an entirely new product is obtained, differing from the original coal in chemical and physical properties. The briquets contain no binding material to soften or disintegrate in the fire. Carbocoal must therefore be recognized not as a mixture, but as a new product, the result of a process of manufacture.

ANALYSIS OF CARBOCOAL

The amount of ash and sulphur in the carbocoal depends upon the characteristics of the coal from which it is made. The summarized proximate analyses of carbocoal, manufactured from 25 different coals at the Irvington plant, are shown in Table 1.

TABLE 1.—*Analyses of Carbocoal*

	From Run of Mine, Per Cent.	From Washed Coal, Per Cent.
Moisture.....	1.00 to 3.00	1.00 to 3.00
Volatile matter.....	0.75 to 3.50	0.75 to 3.50
Fixed carbon.....	82.00 to 88.00	85.00 to 90.00
Ash.....	8.50 to 12.00	7.00 to 10.00
Sulphur.....	0.5 to 1.50	0.6 to 1.50

The percentage of byproducts recovered from clean coal is greater than that recovered from high-ash coals; therefore the careful preparation of the raw coal by washing or other means is profitable.

TAR AND ITS PRODUCTS

The total yield of tar by the carbocoal process is large. Coal containing 35 per cent. volatile combustible produces more than 30 gal. of water-free tar per short ton.

The tar products recovered from the distillation of the coal, at the low temperature used in this process, are different in nature from those obtained in other processes where high temperatures are used. At the lower temperature, there is an abundance of tar vapors, and a relatively small yield of gas of high illuminating value. At the higher temperature these primary products are split up, with a consequent increase in the gas yield and a corresponding decrease in its illuminating value and in the amount of tar vapors recovered. There is also an increase in the percentage of residuals, the pitch increasing from 30 per cent. in the low-temperature distillation, to 64 per cent. or more when high temperatures are used.

The tar obtained in the primary distillation of the coal has a specific gravity of 1.00 to 1.06. It contains a large percentage of light solvent oils, tar acids, and cresols, but very little carbolic acid and no naphthalene or anthracene. The free-carbon content of this tar is low. The light oils contain appreciable quantities of naphthenes, pentane, hexane, hexahydro-benzenes, and also hydrocarbons of the paraffine series, which make these oils valuable as a substitute for gasoline.

A satisfactory method of removing the paraffine and aromatic portions of the light oil has been developed, so that c. p. benzol and toluol can now be obtained by this process. During the low-temperature distillation period, 20 to 28 gal. of tar, including the light oil obtained from the stripping of the gas, are recovered, the exact amount depending upon the volatile content of the coal. This low-temperature tar contains approximately 30 per cent. of pitch and 70 per cent. of tar oils, as compared with 50 to 60 per cent. of pitch and 40 to 50 per cent. of oil products contained in ordinary gas-house and coke-oven tar.

In the second or high-temperature distillation, 5 to 6 gal. of tar are added to the above yield. This tar is heavier than that obtained from the first distillation, and is similar to coke-oven tar.

Table 2 compares the tars and light oils obtained in the production of carbocoal with those obtained in the ordinary byproduct coking processes.

TABLE 2.—*Recovery of Liquid Products per Ton of Raw Coal*

	Distillation Temperature °F.	Byproduct Coke Oven		Carbocoal, First Distillation		Carbocoal, Second Distillation	
		Gal.	Per Cent.	Gal.	Per Cent.	Gal.	Per Cent.
Light oil.....	0-170	0.27	3.47	1.58	6.60	0.003	0.05
Middle oil.....	170-230	0.44	5.85	3.29	13.70	0.036	0.60
Creosote oil.....	230-270	0.78	10.37	3.11	12.95	0.126	2.10
Heavy oil.....	270-360	1.26	16.81	8.88	37.00	2.485	41.42
Pitch.....		4.66	62.18	6.90	28.75	3.290	54.83
Loss.....		0.09	1.32	0.24	1.00	0.060	1.00
Totals.....		7.50	100.00	24.00	100.00	6.000	100.00

In addition to the above yield of tar, there is obtained, in both the byproduct coke oven and the carbocoal process, by stripping the gas, from 2 to 3 gal. of light oil. This yield depends upon the characteristics of the coal carbonized.

Approximately 30 per cent. of the fractions from 170° to 360° F. in the carbocoal process are tar acids; the remainder of the fractions are neutral oils.

The value of the products from the distillation of tar depends, of course, on the extent to which the tar is refined. The fractionation and subsequent treatment of the tar oils, which is a part of this process, give the products shown in Table 3, in carbonizing 1000 tons of coal; the figures are based upon data obtained from carbonizing run-of-mine coal from Clinchfield, Va.

TABLE 3

1. Carbocoal..... 725 tons.

Analysis

	Raw Coal	Carbocoal
Moisture.....	0.72	1.84
Volatile matter.....	35.01	2.75
Fixed carbon.....	57.23	85.64
Ash.....	7.04	9.77
	100.00	100.00
Sulphur.....	0.63	0.52

2. Sulphate of ammonia..... 20,000 to 25,000 lb.
3. Other nitrogen products, principally pyridine bases 2,000 to 4,000 oz.
4. Motor spirits..... 1,800 to 2,200 gal.
(or c. p. benzol, 250 gal., c. p. toluol, 500 gal., motor spirits, 1000 gal.)
5. Crude tar acids, principally cresylic acids..... 4,040 gal.
6. Water-white naphthas..... 3,500 gal.
7. Creosote oil..... 5,450 gal.
8. Heavy creosote oil..... 4,660 gal.
- Other products, used in process:
9. Pitch..... 10,000 gal.
10. Gas, of 530 B.t.u., approximately..... 9,000,000 cu. ft.

Pitch is always an element of questionable value in tar distillation. The Smith process, however, utilizes all of its pitch for briquetting the semi-carbocoal produced by the first distillation. Moreover, the valuable portions of this pitch are recovered in the tar and gas resulting from the second distillation. It is therefore noteworthy that all the tar products recovered by this process are oil derivatives.

AMMONIUM SULPHATE

The primary distillation of the raw coal gives only a small yield of ammonium sulphate. The secondary distillation of the raw briquets, however, brings the amount up to approximately 21 lb. per short ton of raw coal carbonized.

GAS

In the primary distillation of the raw coal, from 5000 to 6000 cu. ft. of gas per short ton of coal is recovered. This has a heating value of 650 to 700 B.t.u. per cubic foot. The distillation of the briquets yields also about 4000 cu. ft. of gas of 350 to 400 B.t.u. per cubic foot. The process in its present stage of development uses all of the gas recovered from both distillations.

AVAILABLE COALS

The carbocoal process has been applied to both coking and non-coking coals. It has been found to work satisfactorily with the non-coking coals of Utah, Washington, and Illinois, and the coking coals of Pennsylvania, Virginia, West Virginia, Tennessee, and British Columbia. Through the application of this process, many of the black lignite or sub-bituminous coals of our Western States may be converted into a fuel of higher economic value.

BYPRODUCT GAS PRODUCERS

Another application of the Smith process equal in importance to the manufacture of carbocoal is the adaptability of a certain part of the process to the production of electric power. The carbon residue, or semi-carbocoal, the residue of the primary distillation, is a non-caking fuel, practically tar free. Although representing 72 per cent. of the originally coal by weight, it contains nearly all the nitrogen originally in the coal. It therefore provides an ideal fuel of high nitrogen content for the byproduct producer. A combination of this kind would recover the maximum percentage of tar and ammonia products, with a large yield of low B.t.u. gas, which can be burned satisfactorily under steam boilers, and thus produce cheap power.

Byproduct gas producers have been used to a considerable extent in Europe, where fuel is expensive and where non-caking coals have been available; but in America the development of this industry has been retarded by difficulties arising from the use of caking coals.

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A Concrete Example of the Use of Well Logs

BY MOWRY BATES,* TULSA, OKLA.

(Colorado Meeting, September, 1918)

THE following example of the practical application of engineering geology is of interest in that it demonstrates the advantage of keeping accurate records of all wells, whether drilled by one's self or by others, together with the advantage gained by gathering such data during the process of development. The fault described was found in the autumn of 1915, during the hurried development caused by the discovery of the famous Gusher Bend pool in Red River Parish, Louisiana. The writer was at the time employed by one of the operating companies as geologist, and the example is a portion of the routine work.

LOCATION

The oil fields of northern Louisiana and east Texas are located in Caddo, Bossier, De Soto and Red River Parishes, Louisiana, and Marion County, Texas. A very narrow strip of the eastern portion of the latter is productive. The producing oil pools are known as the Caddo Field, in the northern part, and the De Soto-Red River Field, in the southern. The two fields are 60 miles apart. There are several gas fields between them, but no important supply of oil has been found, though there are several producing wells in the Anona chalk, locally called the chalk rock, in the Elm Grove gas field in Township 16 North, Range 11 West (see Plate 1).

GENERAL GEOLOGIC AND STRUCTURAL FEATURES

The general geology of northern Louisiana has been excellently described by A. C. Veatch in *Professional Paper* No. 46, U. S. Geological Survey; by G. D. Harris, *Bulletin* No. 429, U. S. Geological Survey; and later by George C. Matson and Oliver B. Hopkins in *Bulletin* No. 619 and 661C, U. S. Geological Survey.

* Petroleum geologist and engineer.

The portion of the section referred to in this paper is that lying below the Wilcox formation and the flood plain of the Red River, which drains the Red River oil field.

The Red River runs through approximately the center of the field and is paralleled by lateral bayous or old river channels. The river bottom, at this point about 12 miles wide, is filled with alternating sands, clays or gumbos, and gravel, having a depth as great as 120 ft. Both to the east and west of the bayous, rise low sandy hills, rarely attaining an elevation of more than 100 ft. above the river bottom. The only surface exposures are Wilcox sands and clays, of Eocene time. The formations are so soft and easily eroded that it is impossible to do any detailed surface work unless one encounters one of the thin seams of lignite which are found at from 60 to 200 ft. below the surface. It is seldom that these seams are exposed except along the banks of the bayous and it is difficult to correlate them or even find them. All work must therefore be done from the study of well records.

Below the Wilcox sands and clays are the Midway and Arkadelphia formations, which are supposed to be respectively the Lower Tertiary and the uppermost formation of the Cretaceous. As both consist of a few thin, soft sandstones in thick soft shale and clay deposits, it is impossible to differentiate them, and in the study of records one is compelled to disregard both.

Fortunately the next formation below is a hard sand, which often has a calcareous capping, making it easily distinguished in drilling. This is the Nacatoch sand or, as it is locally called, the Gas rock. In the Red River Field it has an average thickness of 130 ft., though this varies greatly to the east and the west, and in some of the wells in the south central part of the state the Nacatoch cannot be distinguished with certainty.

Below the Nacatoch is the Marlbrook marl, consisting of blue to white shales. We then come to the Anona chalk, which is about 100 ft. thick. Below the Anona is another thick bed of blue and white shales, with some irregular sand, known as the Brownstown marl.

Below the Brownstown is the Eagle Ford shale, which includes the Blossom sand member, called the sand rock, or lower gas rock, by the drillers. The Eagle Ford is composed of varying sands and shales, with no regular order or thickness until near the bottom, where a soft limestone is found, as shown in the section. It is just below this lime that the oil-bearing sands are found. The exact age of the producing sands is at present somewhat uncertain. It was assigned to the Woodbine for a number of years, but a fossil found in a deep well, which assuredly came from the bottom of the well, has been assigned by Stephenson to the Eagle Ford, which would place the producing sand somewhere in the lower portion of this formation.

Generalized Section of Formations Supposed to Underlie the De Soto-Red River Oil Field, Louisiana

System	Series	Thickness, Feet	Group	Formation
Quaternary...	Recent			
	Pleistocene	0-200		
Tertiary....	Eocene.....	300-900	.....	Wilcox
		200-300	.....	Midway
Cretaceous...	Gulf (Upper Cretaceous)	300-600	.....	Arkadelphia clay
		100-160	.....	Nacatoch sand
		150-750	.....	Marlbrook marl
		+100	.....	Anona chalk
		150-500	Austin.....	Brownstown marl
		400-700	.....	Eagle Ford shale (in- cluding Blossom sand member)
				Woodbine sand
		0-400	Washita.....	Denison
				Fort Worth limestone
				Preston
	Comanche (Lower Cretaceous)	25- 30	Fredericksburg	Goodland limestone
		500-800	.....	Trinity sand

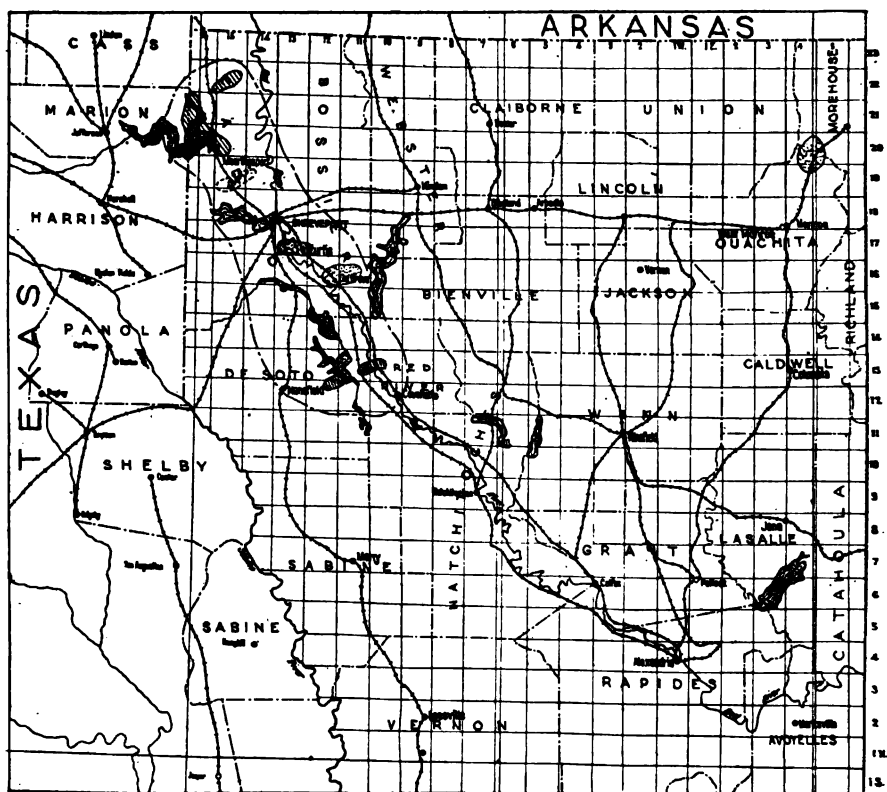
The Red River oil field is in the southern part of the Sabine uplift, the higher portion of which is outlined in the key map (Fig. 1). The oil is found in a series of domes which are superimposed on a long narrow fold running from the center of Twp. 12 North, Range 12 West, to the center of Twp. 13 North, Range 10 West. The western portion of this fold is known as the De Soto oil field, the eastern as the Red River-Crichton oil field.

THE RED RIVER-CRICHTON OIL FIELD

The Red River-Crichton oil field is situated almost entirely in the Red River bottom, though a small portion of the eastern end is in the hills east of Coushata Bayou. It was opened in 1914 by the Gulf Refining Co., who drilled a well in Section 14, Twp. 13 North, Range 11 West. A short time later Wolfe & Keen drilled Weiss No. 1 in Section 18, Twp. 13 North, Range 10 West. The latter well had an initial production of

6500 bbl. per day and produced many thousand barrels before any offset wells were completed.

In the late summer of 1915, a well was drilled on a small lease in the northwest corner of Section 25-13-11, which started the famous Gusher



MAP SHOWING OIL AND GAS POOLS
IN
NORTHERN LOUISIANA AND EAST TEXAS.

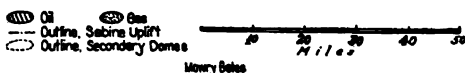


FIG. 1.

Bend pool. The leases were all small, and a large number of wells were drilled very close together. Wells came in as large as 4000 bbl. per day, but the decline was very rapid, owing to the loose character of the sand and the closeness of the drilling.

METHOD OF MAPPING STRUCTURE

A study of a large number of well records in the various Louisiana fields indicated a close relationship between the producing sand and the Nacatoch sand above. The interval was found to be fairly constant in the various pools, though it varied considerably from one pool to another. In the Crichton field the interval from the Nacatoch to the producing sand is about 1670 ft. The attitude or form of the Nacatoch sand is represented by contours, the figures on the contours (Fig. 2) being the

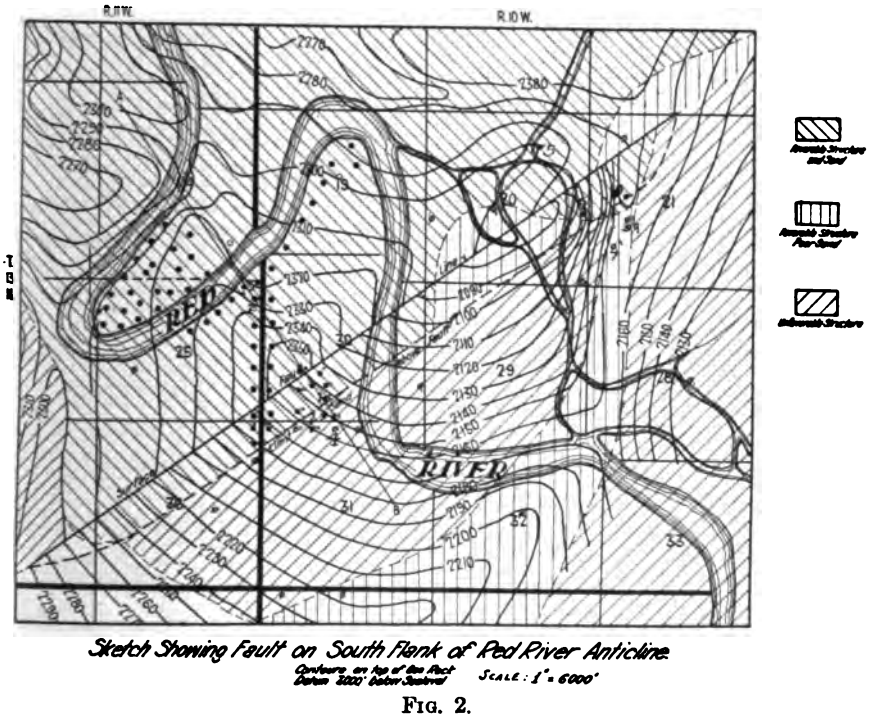


FIG. 2.

elevation of the top of the Nacatoch sand above a datum plane 3000 ft. below sea level. This datum is taken in order to have positive contours, the larger numbers being higher. The Nacatoch sand is selected as the key rock because of the marked change in character from the Arkadelphia clays immediately above, whereby the top of the Nacatoch can be immediately detected and recorded. The interval to the oil sand is sufficiently constant to be useful, and the shallow depth enables one to keep ahead of development in close-in work and project structure in advance of the drill.

THE RED RIVER FAULT

The development of Section 25, 30, 20 and 21 was proceeded with as rapidly as possible. The writer was at all times collecting records from various sources and plotting them in order to keep in advance of the drill. It was at first thought that the southern line of Section 25 and 30 were in a syncline, as indicated by elevations of the Nacatoch from the

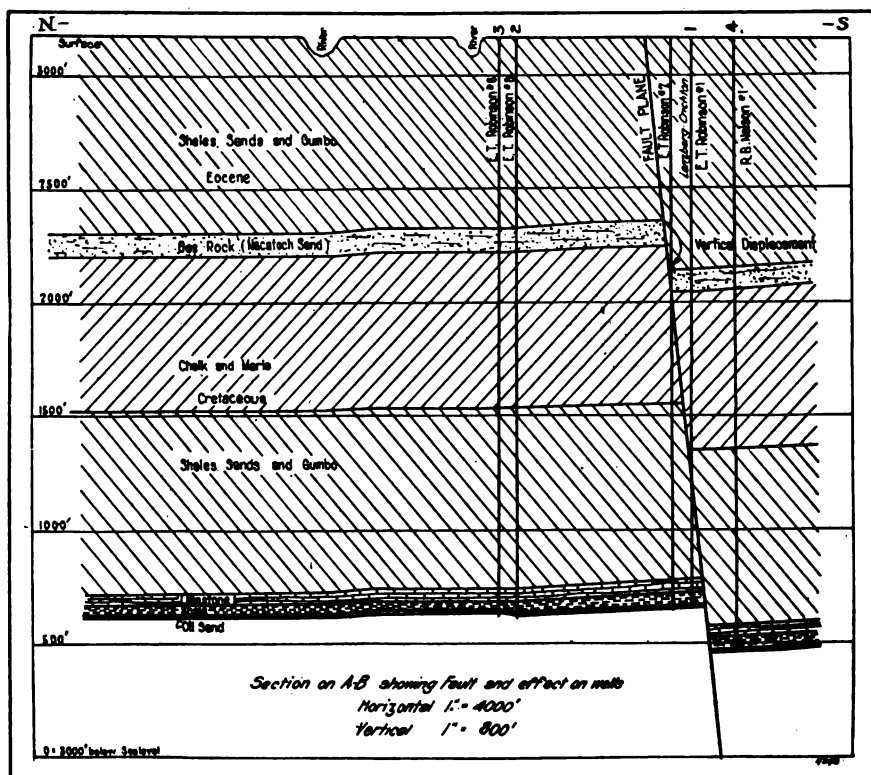


FIG. 3.

well in the center of Section 32. Then the well marked 1 in Section 30 came in, making 3000 bbl. where a dry hole or a small well was expected. This log was kept secret, and we did not have the depth of the Nacatoch until we secured the entire log. It was then found to be on the top of a dome the higher part of which had been thought to be farther to the northwest. A glance at the log showed a marked difference from any other in the field. The interval to the Nacatoch, instead of being 1682 ft., as in well No. 3 to the northwest, was only 1472 ft., or 210 ft. less than it should have been. It was at once apparent that faulting was

present. The same day, wells No. 6 and 8, in Section 20 and 21 came in, showing intervals of 187 and 111 ft., respectively.

A study of all literature and records of normal faults in soft formations indicated that the majority had dips between 50° and 70° . A dip of 60° was assumed, and the fault plotted. Fig. 2 is the original contour map, which it has not been necessary to change since the first draft. Fig. 3 is Section A-B as marked on Fig. 2. It was estimated that a well drilled over 282 ft. south of well No. 1 would be beyond the limit of the producing sand, and would pass through the same horizon 210 ft. lower, which was sufficient displacement to throw the producing sand below the water level. This would cause dry holes in an area where the accumulation of oil was controlled by the condition of saturated sands, as in this field. This was found to be accurate within 14 ft. when well No. 4 was completed. The same condition was found to exist in the wells along the fault to the northeast, and it was feasible to predict a well or a dry hole from the location on the map. The distance south of the fault to which the producing sand might extend was, of course, controlled by the amount of displacement at each point.

After locating the fault underground, it was found on the surface between wells No. 8 and 9, where a sand rests against a clay. Matson and Hopkins, in *Bulletin* 661C, U. S. Geological Survey, extended the fault much farther to the southwest than I have done, but the evidence indicates that the extent mapped is correct.

The mapping was so accurate that the well immediately north of No. 1 was due to pass through the gap, or break, in the Nacatoch sand; which, in fact, it did, and it is the only well in the field in which no gas rock is encountered.

An interesting point discovered in the subsequent drilling of the wells to the south of the fault was found in well No. 4, which made some 30,000,000 cu. ft. of gas the first day; toward evening of the second day after drilling in, water began to show and in a few hours the well went entirely to water. This is explained by the theory that the dome was almost completely formed and the accumulation of gas had begun before the faulting took place. If the 2190-ft. contour south of the fault is extended to the southwest, and the higher contours are sketched in their proper relations, it will be found that a dome is shown with its high point a little south of the present high; and where the syncline is shown south of the fault a gradual southeasterly dip will be found. When the faulting occurred, the gas collected in the higher portion of the dome, and to the south of the fracture it was trapped and carried down in the sand. It was sealed in place by the water coming in from the south, and when tapped by the drill it made a large gas well for a short time, until the pressure was reduced and the water was allowed to come in from the higher structure to the south.

The Gusher Bend dome followed the usual rule of the minor structures on the Sabine uplift in having thinner and more compact sands on the southern flank, the thicker and more favorable sands being found on top and on the north flank. Hence the small favorable structures to the south of the fault were barren except for a limited amount of gas and the usual slight showing of oil which is found in so many wells in northern Louisiana.

The economic value of the above work was not appreciated at the time by the writer's superiors. The company for whom the work was done was not fully convinced as to the reliability of this type of study and against his advice proceeded with the drilling. Every well south of the fault was dry, as predicted, and many thousands of dollars were spent without results.

DISCUSSION OF THIS PAPER IS INVITED. It should preferably be presented in person at the Colorado meeting, September, 1918, when an abstract of the paper will be read. If this is impossible, then discussion in writing may be sent to the Editor, American Institute of Mining Engineers, 29 West 39th Street, New York, N. Y., for presentation by the Secretary or other representative of its author. Unless special arrangement is made, the discussion of this paper will close Oct. 1, 1918. Any discussion offered thereafter should preferably be in the form of a new paper.

The Theory of Volcanic Origin of Salt Domes

BY E. DEGOLYER, NEW YORK, N. Y.

(Colorado Meeting, September, 1918)

I. INTRODUCTION

VOLCANIC origin was among the first of the theories advanced to account for the occurrence of the salt domes of the Gulf coastal plain, northern Louisiana, and eastern Texas, and it is still being re-stated in various forms by the most recent contributors to our knowledge of the geology of such deposits.

Argument has been largely by analogy and attention has repeatedly been called to the Mexican oil fields, particularly those of the Tampico-Tuxpam region, because of the occurrence of oil in close proximity to volcanic plugs in those fields, an occurrence supposed to have some resemblance to the common occurrence of oil in the salt domes of the United States.

The author, having spent several months of the past year in a general study of salt domes and in a detailed study of certain domes in the United States, and having been acquainted for some time with the exploration of similar domes in the Isthmus of Tehuantepec region, Mexico, and with the general geology of the Tampico-Tuxpam region, Mexico, has reviewed the various theories of volcanic origin for salt domes which have been advanced to the present time. The purpose of this paper is to present such review and to discuss the supposed Mexican analogy.

II. REVIEW OF VOLCANIC THEORY

R. Thomassy¹ who had visited the Five Islands of Louisiana between 1857 and 1859, in 1860 described them with some care, noting their distinct character, alignment, and similarity, and ascribing to them a volcanic origin. He regarded them as being akin to the mud lumps in the delta of the Mississippi and was impressed by their symmetry and by the ponds or lakes which occur on several of the islands and which he regarded

¹ R. Thomassy: *Géologie pratique de la Louisiane*. Paris, 1860. See particularly Chapter 8 on the intervention of hydrothermal and volcanic forces in the formation of lower Louisiana.

as being of extinct crater types. He believed that he detected evidence of corrosion by thermal and acid waters on certain rocks found near Petite Anse and supposed that these rocks had been ejected from the depths of the Gulf through explosive action. He apparently suspected the presence of rock salt and regarded it as resulting from the evaporation of sea water by volcanic heat.

In May, 1862, the main mass of salt was discovered at Petite Anse by a negro who was cleaning out and deepening one of the old brine wells under the direction of John Marsh Avery. This was the first discovery of the salt nucleus so characteristic of the domes, and observers first began to learn something of their true structure.

Thomassy² again visited the Island and first brought the salt to the attention of the scientific world, recalling his theory of volcanic origin "in the sense that it (Petite Anse) comes from a volcano of water, mud, and gas," and repeating from his former work the theory that the rock salt was formed from the evaporation of sea water by volcanic heat.

Richard Owen,³ in 1865, while serving in the Federal Army and stationed at New Iberia, studied the Petite Anse deposit cursorily and concluded that the Island was not of volcanic origin but that the salt was produced by the evaporation of sea water in lagoons which were cut off from the sea by low barriers but were continually being filled with sea water at occasional high tides.

Goesmann,⁴ in 1867, reported on the Petite Anse deposit. He rejected Owen's salt-pan theory and suggested that the salt resulted from the evaporation of brine springs originating from beds of rock salt in some older geological formation; a theory akin to the later and more elaborate ones of Hill and Harris.

Eugene W. Hilgard⁵ examined this same deposit in 1867, at the request of Joseph Henry of the Smithsonian Institution, and concluded that the island was not of volcanic origin, but was a Cretaceous outlier, with cappings of drift and other alluvial material, the salt itself being of Cretaceous age. He suggested a genetic relationship between the salt deposit and the Calcasieu sulphur deposit.

² R. Thomassy: *Supplément à la géologie pratique de la Louisiane. Ile Petite Anse. Société Géologique de France, Bulletin*, 2d series (1863), **20**, 542-544, plate.

³ Richard Owen: Report on Quaternary Rock Salt Deposits in Louisiana. *St. Louis Academy of Science, Trans.* (1868), **2**, 250-252.

⁴ C. E. Buck and C. A. Goesmann: On the Rock Salt Deposit of Petite Anse, Louisiana Rock Salt Co. *Report of the American Bureau of Mines*; 35 pages, 2 plates, New York, 1867. Original source not consulted. Goesmann is quoted by H. C. Bolton, *New York Academy of Science, Trans.* (1888), **7**, 124-125.

⁵ E. W. Hilgard: On the Geology of Lower Louisiana and the Salt Deposits of Petite Anse Island (1872). *Smithsonian Contributions, Separate No. 248*, 32-34, Washington.

Otto Lerch, in 1893, published two papers setting forth the results of his observation of geological features including the salines in north Louisiana. In the first of these papers⁶ he concludes that no volcanic eruptions and no violent contortions have disturbed the geological formations of north Louisiana; and in the second paper,⁷ after noting that the existence of the salines can only be traced along the summit of a Cretaceous ridge, which traverses the State diagonally from its northwest corner to the Island of Petite Anse, he arrives at a conclusion which combines to some extent both Hilgard's outlier theory and a theory similar to volcanic origin. It was his idea that at the close of Mesozoic time enormous plutonic forces had thrown up mountain chains of vast extent and that the isolated peaks in the mountain chains thus formed had served as Cretaceous outliers in the Tertiary sea. He was further of the opinion that the Balcones fault and the basaltic outbreaks along it are of contemporaneous origin.

T. Wayland Vaughan,⁸ in 1895, expressed opinions very similar to those of Hilgard with regard to the origin of the north Louisiana salt domes.

Clendenin,⁹ as a result of investigations during the summers of 1894 and 1895, in 1896 expressed the opinion with regard to Thomassy's theory that he could not interpret any evidence seen as proof of powerful volcanic convulsions. He rather followed Hilgard, whom he quotes extensively, but suggested, somewhat after Lerch, that the Cretaceous outliers are the result of differential elevation rather than differential erosion. He recognized clearly the earth movement during comparatively late geological time.

A. C. Veatch¹⁰ early in 1899 left off his study of the salines of north Louisiana to investigate the Five Islands. He states that only two of the islands at the time furnished definite data on the method and date of their formation, Belle Isle showing a very distinct dome-shape fold and Petite Anse seeming to represent a fault block. He thought that the faulting might possibly be due to solution of the underlying salt but that

⁶ Otto Lerch: A Preliminary Report upon the Hills of Louisiana, North of the Vicksburg, Shreveport and Pacific Railroad. *Louisiana State Experiment Stations, Geology and Agriculture* (1893), 1, 27.

⁷ Otto Lerch: A Preliminary Report upon the Hills of Louisiana, South of the Vicksburg, Shreveport and Pacific Railroad, to Alexandria, La. *Louisiana State Experiment Stations, Geology and Agriculture* (1893), 2, 53-109.

⁸ T. W. Vaughan: Stratigraphy of Northwestern Louisiana, *American Geology* (1895), 15, 208-229.

⁹ W. W. Clendenin: A Preliminary Report upon the Florida Parishes of East Louisiana and the Bluff, Prairie, and Hill Lands of Southwest Louisiana. *Louisiana State Experiment Stations, Geology and Agriculture* (1896), 3, 236-240.

¹⁰ A. C. Veatch: The Five Islands, Louisiana. *Louisiana State Experiment Stations, Geology and Agriculture* (1899), 5, 259-260, pls. 19-31.

it was probably due to orographic movements and concluded that the formation of the island began with a possible initial movement (evidences of which had thus far been seen only on Petite Anse) in probably late Tertiary time, that the main folding and faulting which occurred in the Pleistocene was followed by the depression of the whole coastal region and deposition of the upper yellow clays, that during the succeeding high level period the deep channels of the coastal rivers were excavated and the lake valleys formed on the Island and that the subsidence which followed had continued to the present day. These views by Veatch are particularly interesting in view of his subsequent independent promulgation of a theory of volcanic origin.

In 1896, A. F. Lucas found salt under Jefferson Island, or Cote Caline, and thus initiated the most fruitful part of his long period of study and prospecting of the domes of the Gulf coastal plain; a work which culminated so successfully and happily in his bringing in of the discovery well of the Spindletop pool and of the coastal oil fields in January, 1901. This discovery gave impulse to the intensive exploration by the drill of the various salt domes of the coastal plain, operations from which we have gathered most of our present knowledge regarding the occurrence of the salt domes and without which we should still be but little removed from the speculative days of Thomassy and Hilgard.

Lucas, in 1896¹¹ and 1898,¹² published two papers on Louisiana salt and in 1899¹³ published a third and more complete one. He was more concerned with occurrence than origin, merely noting a belief that the geological formation of the Five Islands is Quaternary, while the salt deposits belong to the Tertiary period and are supposed to rest on the Cretaceous and that the salt formation at Jefferson Island does not lie in undisturbed stratification but seems to have been folded and contorted while still in a plastic condition. Lucas clearly recognized the existence of the dome structure of Spindletop but was inclined to think that it was due to gas pressure.¹⁴

Harris¹⁵ at first regarded Spindletop as a Cretaceous fold.

Robert T. Hill,¹⁶ in 1902, published his theory that the salt of the domes is one of the resultant products of columns of hot saline waters ascending under hydrostatic pressure.

¹¹ A. F. Lucas: The Avery Island Salt Mine and the Joseph Jefferson Salt Deposit, Louisiana. *Engineering and Mining Journal* (Nov. 14, 1896), **62**, 463-464.

¹² A. F. Lucas: Louisiana Salt Resources. *American Manufacturer*, Pittsburg, Pa. (Dec. 23, 1898), **63**, 910-911.

¹³ A. F. Lucas: Rock Salt in Louisiana: *Trans.* (1899), **29**, 465-466.

¹⁴ Robert T. Hill: The Coast Prairie of Texas, *Science* N. S. (1901), **14**, 327.

¹⁵ *New Orleans Picayune*, Mar. 27, 1901, requoted from Harris, 1907.

¹⁶ Robert T. Hill: The Beaumont Oil Field, with Notes on the Other Oil Fields of the Texas Region. *Journal of the Franklin Institute* (1902), **154**, 273-274.

Veatch,¹⁷ reported on the salines of north Louisiana in detail, in 1902, but did not express any modification of his views as expressed for the Five Islands.

Eugene Coste,¹⁸ in 1903, advanced the theory that the salt domes are the result of "volcanic emanations bringing the water, salt, sulphur, oil and gas from the interior in the state of vapors and gases, which condensed more or less near the surface" etc. He regarded the domes and salt masses as "the dying distant echo of that tremendous volcanic energy which, a little farther south, in Mexico, Central America and in the islands and along the southern coast of the Caribbean Sea, is to this day so powerfully active."

Lee Hager¹⁹ presented, in 1904, an able paper summarizing the existing knowledge regarding the southern salt domes and proposed, in greater detail, a theory somewhat similar to that proposed by Coste. Hager's theory is essentially as follows:

By contact with the molten intrusives, vast quantities of gas were generated from the reduction of metallic sulphides and the distillation of lignites and organic substances. These gases, accompanied by steam under tremendous pressure, forced their way to the surface through the unconsolidated sands and clays of the overlying Tertiary material, perhaps giving rise to mud volcanoes, such as occur in many of the world's great oil fields at the present day. Heated waters from great depths found vent along the same channels, carrying in solution carbonates of lime and magnesium, gypsum and salt. By ebullition and evaporation these solutions became concentrated until, saturation resulting, precipitation commenced, forming the neck-like masses of salt, gypsum and dolomite now encountered. With the cooling of the intrusive masses and the choking of the vents, the process practically ceased. A period of subsidence followed, during which the Coastal Quaternary beds, which at present cap the mounds, were laid down, followed by a secondary movement along the old lines of weakness, resulting in the present elevation of the mounds above the surrounding prairie.

Hager admits the weakness of his hypothesis to lie in "the assumption of intrusives concerning the existence of which we have no evidence whatever," but finds some support for it in the occurrence of intrusive rocks and the upward displacement by them of overlying strata in the Austin, Texas, area as well as in the common occurrence of some form of vulcanism in most of the world's Tertiary oil fields.²⁰

¹⁷ A. C. Veatch: The Salines of North Louisiana. *Geological Survey of Louisiana, Report of 1902*, 47-100.

¹⁸ E. Coste: The Volcanic Origin of Natural Gas and Petroleum. *Canadian Mining Institute Journal* (1904), 6, 89, 104.

¹⁹ Lee, Hager: The Mounds of the Southern Oil Fields. *Engineering and Mining Journal* (1904), 78, 137-139, 180-183.

²⁰ From his numerous citations of the occurrence of mud volcanoes in various oil fields, one must conclude that Hager regarded them as true volcanic phenomena. While some mud volcanoes are undoubtedly of true volcanic origin, many are known to be only gas seepages through very wet and plastic clays and to give no indications whatever of volcanic origin.

Veatch,²¹ in 1906, after describing the igneous intrusions of southern Arkansas, concluded with regard to the origin of the salt domes of northern Louisiana and eastern Texas as follows:

Whether the forces producing these unique domes were in any way associated with those producing the intrusions just mentioned it is as yet impossible to say; but the irregularity of their distribution, the great symmetry of all the domes which have been carefully studied, the difficulty of explaining this symmetry by any manner of folding not associated with igneous intrusions, and the suggestion which this symmetry carries of force applied at one point from below, just as a sharp-pointed little dome might be formed in a sheet of dough by pushing upward with a blunt pencil, indicate similar igneous intrusions beneath these great thicknesses of relatively plastic, recently deposited cretaceous sediments as the cause of these domes.

This conclusion, so similar to that previously put forward by Hager, was arrived at independently by Veatch, who had not yet become acquainted with Hager's theory.

Harris,²² in 1907, suggested that the domes were formed by "concretion-forming forces as well as the power of crystallization," and concluded that though the domes might be "located along lines of weakness, faults, or fractured anticlines, they are not to any great extent due to tangential, mountain-making forces, nor volcanic upheavals, nor igneous plugs." He further notes that igneous plugs and dykes usually cause great irregularities in the earth's magnetic fields and notes that the area under consideration, which contains a number of saline domes, shows irregularities entirely too slight to indicate igneous activity in the region. Harris restated and developed his theory further in 1908, 1909 and 1910. In 1909, he²³ called attention to the fact that certain nearby Arkansas volcanic rocks are magnetic.

In 1909, Coste²⁴ elaborated upon his former declaration of volcanic origin for salt domes and noted that,

In the Mexican oil fields the volcanic action has been a little more intense and instead of only the hot gases, vapors and waters piercing up more or less through the horizontal strata to form the salines, as in Texas and Louisiana, we see the volcanic lava cones themselves piercing up boldly through the plains. There is no doubt that these lava cores in Mexico surrounded with petroleum and other solfataric emanations are one and the same volcanic phenomenon as the vertical chimneys of salts, hot waters and hot petroleums of the Texas-Louisiana salines.

Clapp,²⁵ in 1912, concluded with regard to the theory suggested

²¹ A. C. Veatch: *Geology and Underground Water Resources of Northern Louisiana and Southern Arkansas*. U. S. Geological Survey, Prof. Paper 46 (1906), 29.

²² G. D. Harris: Notes on the Geology of the Winnfield Sheet. *Geological Survey of Louisiana, Bulletin* 5 (1907).

²³ G. D. Harris: Magnetic Rocks. *Science*, new ser. (Mar. 5, 1909), 29, 384.

²⁴ Eugene Coste: Petroleum and Coals. *Journal, Canadian Mining Institute* (1909), 12, 290.

²⁵ F. G. Clapp: The Occurrence of Oil and Gas Deposits Associated with Quaquaversal Structure. *Economic Geology* (1912), 7, 377.

by Hager that "his theory would seem to be supported by the existence of volcanic plugs in the Coastal Plain of Mexico, accompanied by many of the Texas phenomena." He states that "these plugs are arranged in straight lines in a manner similar to the saline domes."

Lucas,²⁶ in 1914, states that he has "long held the opinion that igneous rock in the form of laccoliths, batholiths, or sills may underlie the salt domes of Louisiana, Texas, and elsewhere." He further states that he has "held the opinion with Mr. Coste that emanations of gas through these domes constitute evidences of volcanic origin." He concluded, however, that "the salt was not deposited by evaporation, but must have been deposited by saline waters ascending from great depths."

In a still more recent paper, Coste²⁷ continues,

That these are solfataric volcanic emanations is made plain by the occurrences of oil a little farther south, along the same coastal plain, in Mexico. There one can actually observe numerous volcanic necks of olivine basalt, scattered at wide intervals, and also distributed along fault lines similar to the lines connecting the salines of Texas and Louisiana."

Washburne,²⁸ in 1914, seems to favor the volcanic origin of salt domes, regarding the salt as having been precipitated from saturated brines of sedimentary origin by hydrochloric acid from igneous intrusions.

Norton,²⁹ in 1915, suggested still another somewhat complex variation of the theory of volcanic origin, regarding the initiation of the salt deposits as resulting from "the intrusion of molten rocks into the underlying Paleozoic sediments along lines of structural weakness."

Dumble³⁰ regards Norton's paper as one which "seems a step in advance of former ones."

Quite recently, Oliver B. Hopkins³¹ has expressed a view that the structural conditions found at salt domes are such as "are most commonly produced by igneous intrusion, of which no direct evidence has been found in any of the numerous salt domes of the Gulf Coast," and that it is quite probable the forces forming the salt domes "were connected with igneous activity."

²⁶ A. F. Lucas: In discussion of Hoefer's paper on the origin of petroleum. *Trans.* (1915), **48**, 494.

²⁷ E. Coste: Rock Disturbances Theory of Petroleum Emanations vs. the Anticlinal or Structural Theory of Petroleum Accumulations. *Trans.* (1915), **48**, 510.

²⁸ C. W. Washburne: Chlorides in Oil-field Waters. *Trans.* (1915), **48**, 687-694.

²⁹ E. G. Norton: The Origin of the Louisiana and East Texas Salines. *Trans.* (1915), **51**, 508.

³⁰ E. T. Dumble: The Occurrences of Petroleum in Eastern Mexico as Contrasted with those in Texas and Louisiana. *Trans.* (1916), **52**, 263.

³¹ O. B. Hopkins: The Palestine Salt Dome, Anderson County, Texas. *U. S. Geological Survey, Bulletin 661 G* (1917), 264.

Shaw³² has also recently restated the various factors which make the theory of volcanic origin attractive and has discussed briefly the bearing of the Mexican occurrences of oil on the theory itself.

In discussing the weakness of the volcanic theory because of the absence of igneous rock, Rogers,³³ who is at present engaged in a study of salt domes, has noted "the discovery, during the past summer, of volcanic ash in the sediment around one or two of the domes; of a rock resembling a porphyry in a well at Damon Mound; and of an undoubted igneous plug about 50 miles north of the salt-dome belt."

III. EVIDENCE OF VOLCANIC ACTIVITY IN SALT DOME REGIONS

The strength of the volcanic theory of origin of salt domes lies in the fact that the intrusion of a volcanic plug or neck is the only geologic agency now known to us which affects structurally the contiguous sedimentary rocks in the same manner as they are affected by the intrusion of the salt masses. There is considerable variation of form both in salt and igneous rock masses, but the general contour, symmetry, and size of the explored portion of many of the salt masses show a remarkable similarity to like phenomena connected with many igneous rock intrusions.

The weakness of the theory, for the salt dome regions of Texas and Louisiana particularly, lies in the absence of igneous rocks and in the absence of evidence of metamorphism of the sedimentary rocks. The absence of igneous rock may be explained as being the result of deep-seated igneous intrusions which do not nearly reach the surface, but it is hard to conceive of igneous intrusion accompanied by such giving off of hot gases, vapors, and waters as are usually postulated, which would not have resulted in at least a partial metamorphism of the sedimentary rocks forming the walls of the ducts or fissures through which such emanations escaped, presumably the present locus of the salt.

Furthermore, the salt domes give indisputable evidence of movement in quite recent geologic time. If this movement was the direct result of the force of igneous intrusion, one would expect to find some regional evidence of dying vulcanicity such as seismic disturbances, hot springs, etc.

The only evidence of this type which has come to the attention of the author is the high temperature of many of the crude petroleum and underlying waters of the Gulf Coast oil fields. Temperatures ranging from 80° F. or 90° F. to 180° F. have been observed. The only other oil-field temperatures known to the author which are generally higher than these are oil and water temperatures from the Tampico-Tuxpam region,

³² E. W. Shaw: Possibility of Using Gravity Anomalies in the Search for Salt-dome Oil and Gas Pools. *Science*, new ser. (Dec. 7, 1917), **46**, 553-556.

³³ In discussion of Matteson's paper, "The Principles and Problems of Oil Prospecting in the Gulf Coast Country." *Bulletin* No. 136 (April, 1918), 824.

Mexico.³⁴ The Mexican temperatures are very evidently due to latent volcanic heat and it is possible that the Texas and Louisiana temperatures are also the result of volcanic heat.

Harris³⁵ apparently believes the Gulf Coast temperatures can be explained by the normal increase of the temperature of the earth's crust with depth, generally accepted as 1° C. with each 30 m. of depth, or 1° F. per 54.6 ft. The author does not believe that this explanation is satisfactory, but suggests the probability that much of the heat may be the result of chemical reactions. Sulphurous waters are of common occurrence, pyrites of iron, other metallic sulphides and free sulphur are not uncommon, and sulphuric acid has even been found in the domes. It is suggested that a systematic study of temperatures in the Gulf Coast region might throw light on this very interesting subject.

The volcanic theory can also be made to account for the enormous amounts of gypsum, free sulphur, hydrogen sulphide, sulphurous waters and small amounts of metallic sulphides which occur around various of the salt domes. Instead of the sulphur being derived from the gypsum, as is generally suggested, is it not possible that the gypsum is derived from the alteration of limestone by sulphuric acid, as has been suggested by Kennedy,³⁶ who notes that sulphuric acid has been found in many of the domes. It has also been found in volcanic waters.

Sulphur dioxide is one of the commonest of volcanic emanations. By hydration, it readily forms sulphurous acid, which may be further oxidized to sulphuric acid. It also has the power, in the presence of water, of converting chlorine into hydrochloric acid: $\text{SO}_2 + \text{Cl}_2 + 2\text{H}_2\text{O} = 2\text{HCl} + \text{H}_2\text{SO}_4$. The common occurrence of hydrochloric acid in many volcanic emanations suggests that such reaction may occur. The free sulphur was possibly produced by this reaction of hydrogen sulphide, which is also a common volcanic emanation, with sulphur dioxide in the same manner as suggested for solfataric sulphur.

The high sulphur content of the oils from the salt dome fields of Texas and Louisiana is a characteristic which they have in common with the oils of the Isthmus of Tehuantepec salt dome region and the Tampico-Tuxpam region in Mexico, and in which they differ from most other oils. This condition suggests that oils from each of the regions may have been subjected to the action of sulphurous waters and gases of volcanic origin.

Salt itself is one of the commonest of volcanic sublimates but, so far

³⁴ The author has discussed the Mexican temperatures in some detail and given certain Gulf Coast temperatures in an article which has been accepted for the May, 1918, number of *Economic Geology*.

³⁵ G. D. Harris: Oil and Gas in Louisiana. *U. S. Geological Survey, Bulletin* 429 (1910), 8.

³⁶ Coastal Salt Domes. *Bulletin, Southwestern Association of Petroleum Geologists* (1917), 1, 34-59. See particularly pp. 48 and 55.

as is known to the author, no deposits of salt at all comparable in magnitude with those of the domes is known to occur in any volcanic region.

These various mineral occurrences and suggested reactions do not prove the theory of volcanic origin but they do indicate that it accounts for many of the minerals found in the domes as well as do the various other suggested theories.

The actual occurrences of igneous rock in the vicinity of the Texas and Louisiana salt domes consist of certain igneous rocks in southern Arkansas; certain other igneous rocks in the Austin, Texas, area; the igneous mass which forms the oil-producing rock in the Thrall field; and the various occurrences mentioned by Rogers, as already cited.

The volcanic ash mentioned by Rogers as having been found in the sediments around one or two of the domes is of no importance as an indication of volcanic activity in the salt dome region, since the ash may have been air-transported hundreds or even thousands of miles, but the rock resembling porphyry from Damon mound and the igneous plug 50 miles north of the salt dome belt are of considerable importance, and further information as to their occurrence will be of great interest in this connection.

In considering occurrences of igneous rock associated with salt domes, it is worthy of note that Hahn³⁷ states that close connection with propylitic, doleritic, or basaltic extrusions may exist for Algerian salt domes, that relation of salt domes with ophiolitic magma may be probable in the Pyrenees, and that in Germany, dykes of basalt with included fragments of rock salt are observed piercing some of the salt deposits.

IV. THE PROPOSED MEXICAN ANALOGY

Up to the present time, oil in quantity has been encountered in two geologically and geographically distinct regions in Mexico; the Tampico-Tuxpam or northern region, and the Isthmus of Tehuantepec, or southern region.

The Tampico-Tuxpam region consists of that portion of the Gulf coastal plain extending generally from the Soto la Marina River in central Tamaulipas to the Misantla River in north-central Vera Cruz.

The region is made up of a thick series of limestones of Cretaceous age, the equivalent of the Comanche, overlain unconformably by 600 to 800 ft. of alternating thin-bedded argillaceous limestones and shales, which grade imperceptibly into an overlying series of 2000 to 4000 ft. of shales and marls containing occasional thin sandstones and limestones. This shale series, known generally as the Mendez shale, is of Eocene age and is overlain by various series of limestones, conglomerates, sandstones, and shales of Oligocene age, so far as has been determined.

³⁷ F. F. Hahn: The form of salt deposits. *Economic Geology* (1912), 7, 129.

This entire sedimentary series has been folded in Oligocene or post-Oligocene time by the same forces that formed the Sierra Madre Oriental. The rocks of the coastal plain lie in a series of folds more or less parallel to those of the Sierra Madre, the general strike changing from a N.-S. direction in the northern part of the region to a NNW.-SSE. direction in its central part, and a NW.-SE. direction in its southern part, the general dip being toward the Gulf of Mexico. The folds are generally sharp along the mountain front and parallel to it but gradually become less intense as the distance from it increases.

At periods apparently subsequent to the major folding, the region was subjected to considerable volcanic activity and intrusions of volcanic plug, laccolith, dyke, and sill forms occurred. The igneous rock is of basic type, for the most part olivine basalt, but including occasional dolerites, gabbros, etc.

Considerable brecciation and metamorphism of the contiguous sedimentary rocks resulted from the intrusions. Metamorphism by hot waters and gases ascending from the igneous rock was so extensive that in many instances the pipe of metamorphosed rock reached the surface, though the igneous rock did not reach it. This condition exists at the Cerro Tampule in Aguada, Cerro Chapopotal in Cerro Viejo, and at Furbero, where the igneous mass has been reached by the drill at a depth of some 1500 ft. below the surface.

Evidence of any doming around the igneous plugs of this region similar to doming around the salt plugs of Texas and Louisiana is so scarce that it does not seem probable that such structure exists generally. Evidence on this point is very meager, because the geology in the vicinity of the plugs is often masked by talus débris, soil, rank vegetation, etc., but in cases where wells have been drilled near the igneous plugs, there has been little or no evidence of doming.

The oil deposits are not found around these plugs in domed strata, as has often been suggested and as is held by Coste, but in structures formed by the major folding and faulting. Oil is found around the volcanic plugs Cerro de la Pez and Cerro de la Dicha in the Ebano field and conditions appear on the surface to resemble the salt dome fields more nearly than at any other point in Mexico. Ordoñez,³⁸ the only person who has studied this deposit, states regarding this general form of intrusion that "the volcanic plug or pipe of ashy and compact basaltic lava, of which the neck is the upper end, has not produced any considerable disturbance of the shale around it."³⁹ In the Casiano-Tepetate field, where the sedimentary rocks have suffered considerable intrusion, folding and faulting

³⁸ E. Ordoñez: The Oil-fields of Mexico. *Trans.* (1915), **50**, 860.

³⁹ The author has given a number of examples of wells drilled near plugs in another paper, The Effect of Igneous Intrusions on the Accumulation of Oil in the Tampico-Tuxpam Region, Mexico, *Economic Geology* (1915), **10**, 660.

seem to control the occurrence of oil, and instead of the productive pool being developed on top of or around a dome, it seems to be confined to a fold striking N.-S. and bounded by a parallel fault on the west side. The productive area as outlined at present is some $1\frac{1}{2}$ miles long by $\frac{1}{4}$ mile wide.

Some doming by igneous intrusion probably exists. Laccoliths which have domed the overlying strata are common in the San Jose de las Rusias region, Tamaulipas. The oil of the Furbero field occurs in the altered igneous rock of a laccolith or sill, which has been intruded along a plane of stratification of the sedimentary rocks folded previously into a gentle anticline, as well as in the metamorphosed shales which envelop the intrusion. The intrusion of this igneous rock accentuated the pre-existing fold in the overlying beds.⁴⁰ Accentuation to a considerable degree of the normal regional dip on the eastern side of the volcanic plugs Cupelado, Huiltepec, and Dos Hermanos, all lying a short distance southeast of Furbero, has also recently been called to the author's attention.⁴¹ Straight lines suggesting faults are often determined by three plugs in this region but there is no general parallelism between the lines so determined nor with the general structural features of the region. The field evidence does not justify any such conclusion as that expressed by Clapp in stating that the plugs are arranged in straight lines in a manner similar to the salt domes of Texas and Louisiana.

No deposits of salt of the salt dome or other types are known to occur in the Tampico-Tuxpam region. The suggestion by Shaw that gradation phases may be found between salt domes and intrusions and that the salt domes may be absent from the Tampico-Tuxpam region, due perchance to more consolidated rock, would not seem to hold, since salt domes occur in east central Texas in a series of sediments which are quite as consolidated as are the sediments of the Tampico-Tuxpam region.

The Isthmus of Tehuantepec region consists of a portion of the northern coastal plain of the Isthmus of Tehuantepec in the vicinity of Minititlan. It lies almost wholly in the cantons of Acayucan and Minititlan, State of Vera Cruz, and is some 200 miles southeast of the southernmost part of the Tampico-Tuxpam region. Generally speaking, the Isthmus of Tehuantepec is a great E.-W. striking anticlinorium, the folding probably of post Oligocene date, involving Mesozoic and Tertiary sediments. The salt dome region lies on the north flank of this structure. The sediments of the salt dome region are of Tertiary and Quaternary age, except for small patches of Jurassic or Cretaceous limestone which have been brought up by a salt dome near Chinameca.

⁴⁰ The author has described this occurrence in more detail in "The Furbero Oil Field, Mexico." *Trans.* (1916), 52, 286-280.

⁴¹ Personal communication from E. B. Hopkins.

The oldest known rocks outcropping or reached by the drill in the salt dome region consist of a series of massive blue to gray marls, clays, and shales, containing some sandstones. They probably have a thickness of several thousand feet and are of Miocene-Pliocene age. They are overlain by a series of thin-bedded sandstones interstratified with still thinner shales. This formation is of Pliocene age and is overlain in turn by several hundred feet of white to cream colored clays, reddish sands, and thick beds of rounded quartz gravels believed to be of Pleistocene age.

This entire series of rocks has been domed and folded by the intrusion of salt masses, though the unconformable Pleistocene shows so little deformation that it is not believed to have been deposited until after the intrusion of the salt masses was more or less complete.

The salt domes of the Isthmus are very numerous and in places they are closely grouped together. Several of the domes, such as the San Cristobal-Capoacan and the Concepcion, are fairly symmetrical flat-topped domes very similar to those of the Texas-Louisiana region, but others are elongated domes or sharp anticlines. The Soledad and Tecuana domes are of this type.

With the domes are associated impure limestones, gypsum, and generally such minerals as are found in the Texas-Louisiana region. The only known occurrences of igneous rock consist of two isolated outcroppings near Paraje Solo, some 15 miles east of Minititlan, and the volcanic rocks in the San Andres Tuxtla district, adjoining the region on the north and west.

No general alignment of the salt domes of this region similar to that observed in the domes of the Texas-Louisiana region can be made. The structures produced by the salt masses generally resemble folds rather than symmetrical domes occurring at the intersections of faults. These folds may often be traced from one dome to another, the surface geology being much better exposed than in the Gulf Coast region of the United States.

V. CONCLUSIONS

The lack of evidence of any considerable volcanic activity in the salt dome regions of Texas and Louisiana or in the salt dome region of the Isthmus of Tehuantepec, Mexico, as well as the entire absence of any salt masses of the nucleus type in the Tampico-Tuxpam region, Mexico, a region of considerable volcanic activity, would seem to argue most strongly against the acceptance of the volcanic theory of salt dome origin.

The volcanic theory affords a plausible origin for the sulphur, sulphides, certain of the gases, the mineralization of waters, and indirectly the alteration of limestone into gypsum, but it is of little more service in this respect than other theories. It affords also an acceptable source

of heat in accounting for the high temperatures of oil and water in the Texas and Louisiana dome region, but in view of the various minerals present in the domes, heat from chemical action would seem to afford quite as satisfactory an explanation.

Finally, since the attractiveness of the theory of volcanic origin of salt domes lies in the similarity of structural effect produced by the intrusion of the salt in many domes to that produced by the intrusion of the igneous rock of a volcanic neck or plug, it follows that we are interested in the conditions and forces which caused the salt to act in a manner so like to that of an igneous magma. To argue that because the structural effects produced by salt and igneous intrusions are identical, the former is a result of the latter, is little more acceptable than to argue that the latter is a result of the former, and only seems less reasonable perhaps because igneous plugs and the forces forming them are of more common occurrence and are better known than the rarer salt dome types.

It is difficult to conceive of the formation of a tip of salt over 3000 ft. thick, as at Humble, on the end of an igneous plug during the course of or preparatory to an upward thrust which would result in the considerable displacement of contiguous rocks, as at the Palestine, Texas, salt dome where the displacement was 3000 to 3500 ft. Furthermore, the salt may take other forms resembling igneous intrusions, such as the probable laccolithic form of the salt in the Tecuanapa dome, Isthmus of Tehuantepec region; a form which does not lend itself to any theory that it is underlain by a similar igneous intrusion.

Rather, the structure of the domes would seem to make it evident that the salt itself must have flowed. Such flowage was most likely due to great pressure exerted upon buried salt masses by the weight of overlying rocks, and at considerable temperatures and probably accompanied, as has been suggested by van der Gracht,⁴² by recrystallization of the salt. This flowage theory has long been held by European geologists and seems to have been fairly well established by them for certain salt plugs where the geology is well exposed both at the outcrop and by underground workings.⁴³

The marked resemblance between certain of the European salt domes and those of the Texas-Louisiana and Isthmus of Tehuantepec regions, and the difference of the salt domes from other known forms of salt deposits, suggest most strongly certain genetic similarities. The author believes that the theory of intrusion of salt by flowage must receive in future more consideration from American geologists than it has in the past.

⁴² The Saline Domes of Northwestern Europe, *Bulletin, Southwestern Association of Petroleum Geologists* (1917), 1, 85-92.

⁴³ F. F. Hahn: The Form of Salt Deposits. *Economic Geology* (1912), 7, 120-135.

TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS
[SUBJECT TO REVISION]

DISCUSSION OF THIS PAPER IS INVITED. It should preferably be presented in person at the Colorado meeting, September, 1918, when an abstract of the paper will be read. If this is impossible, then discussion in writing may be sent to the Editor, American Institute of Mining Engineers, 29 West 39th Street, New York, N. Y., for presentation by the Secretary or other representative of its author. Unless special arrangement is made, the discussion of this paper will close Oct. 1, 1918. Any discussion offered thereafter should preferably be in the form of a new paper.

Oil in Southern Tamaulipas, Mexico

BY EZEQUIEL ORDOÑEZ, MEXICO CITY, MEXICO

(Colorado Meeting, September, 1918)

THE great activity with which the oil resources of the northern Cantons of the State of Veracruz have been developed has largely resulted from the great success obtained by the important explorations carried out since 1902 in the Ebano district in the North, and several years later near Tuxpam, in the South. It must not be thought that these successes were quickly obtained, since the preliminary studies by good experts, the acquisition of what were thought to be the most promising coast lands, the extensive clearing thereof, and finally the number of unsuccessful drillings at great depth, signified an original outlay of some tens of millions of dollars before finding commercial oil.

The discovery of oil in industrial quantities at Cerro de la Pez, Ebano district, and the famous Dos Bocas gusher some years later, which was burned, once and for all made famous the Veracruz coast, where today is concentrated the Mexican output of mineral oil. In 1917, this production was nearly 50,000,000 bbl. It is well known that this output represents only a fraction of what the wells in actual production can furnish, because with adequate means of transportation and storage, the present extraction could be somewhat over 300,000,000 bbl. a year.

These enormous potential oil resources of the Veracruz coast proceed from a relatively small number of wells, scattered over a few oil fields, separated from each other by large unexplored areas, wherein may be found other favorable fields which, in time, will undoubtedly become just as great centers of oil production.

Experts who know our Gulf Coast believe that lands with commercial oil resources lie not only between the Pánuco and Tuxpan Rivers, but that indications are that the oil zone of Mexico, with more or less interruption, takes in the coast zone from Northern Tamaulipas to the foot of the Sierra Madre of Chiapas, and the banks of the Usumacinta River. This generalization is not merely the outcome of optimism, but is the result of the persistency with which one finds, throughout this Gulf Coast, the most usual characteristics upon which we depend for recognizing oil-bearing lands.



In this short paper, we can discuss only the oil possibilities which, in our opinion, exist in that part of the State of Tamaulipas extending southward from the Soto la Marina River and its tributaries, that is to say, south of the San José de las Rusias property, which everyone is watching at present, because the Corona company is making certain very important explorations there.

The wide coastal belt and littoral of Tamaulipas, in the district near Tampico, to the north of the Tamesi River, with its low lands, lagoons and belt of sandstone hills reaching almost to the San Andrés lagoon, sheltered on the sea side by sandy dunes, greatly resembles the sea shore and coast of the Canton of Ozuluama to the South of Tampico, in the State of Veracruz. The Pánuco and Tamesi Rivers, at their joint outlet to the sea at Tampico bar, have cut through a chain of hills which is merely an extensive strip of Neozoic formation which has largely disappeared over a great part of the interior. Before the Pánuco opening existed, from the outskirts of Tampico to the sea, the waters of the Pánuco undoubtedly emptied into the Gulf through various channels, representing the overflow from a very extensive lagoon stretching for many kilometers inland, which is now drained. This explains the estuary material covering the entire coast for 50 km. inland, including oyster banks and other sea shells as far as Topila, and those estuary deposits and aluvions which have adhered to the first high undulations to the west and at a considerable distance from Tampico.

In the southern part of the State of Tamaulipas, there is a vast area of low-lying gently undulating coast, measuring over 150 km. from east to west, and about the same from north to south, with an elevation of from 100 to 200 m. above sea level. This low-lying coast continues toward the northwest by a wide valley which, rising gently, is used by the railway between Tampico and Ciudad Victoria. This flat southern coast of Tamaulipas is bounded on the west by the Sierra del Abra, or Tanchipa. To the north, the Buena Vista and Sierra Azul ranges, forming part of the Sierra de Tamaulipas, form higher valleys. Important units of the Sierra Azul are joined by hills to a coast range, not very high, called San José de las Rusias. The flat coast, mentioned above, extends south to Veracruz territory beyond the Pánuco and Tamesi Rivers. On this coast, in Tamaulipas, there are only two important breaks which are of importance from the point of view of oil possibilities; these are: (1) The beautiful peak known as Bernal de Horcasitas, which resembles a sharp and narrow crest supported by a cone with a very wide base, the top of the rocky crest being over 1000 m. above sea level. (2) The group of mountains situated near the village of Presas Aldama, dominated by the Cerro Cautivo, the top of which is some 650 m. above sea level. The slopes of this mountainous mass approach the sea shore between Tordo bar and the sandy Point of Jerez.

Both the Bernal and Cautivo mountains, separated by a distance of 70 km., are volcanic and their bases are formed by extensive flows of basaltic lava; both mountains are very recent. Bernal has a relatively short formation history, implying lava flows in close succession from one or few craters, after which eruptions a lava cap formed over the principal crater and filled it; the crater has disappeared by erosion and the lava neck has a graceful appearance as seen from the distance. The Cautivo mountain mass is very different. Here we find a group of volcanoes having a much longer period of activity, during which numerous lava flows overlapped one another, building the whole mass higher and higher. On the summits can be identified various craters, some of considerable dimensions. Among the most recent ones we may mention one of explosive type situated on the southern slopes of the Zapotal crest. This crater has a diameter of about 1.5 km. and is about 100 m. deep at its lowest edge, with an extensive flat surface in the bottom. The walls of the crater are of basalt, basaltic breccia and tufa, with limestone, sandstone and marl coming from the adjoining formation underlying the eruptive rock.

The importance of the eruptive center of the Cerro Cautivo, in the neighborhood of the village of Presas Aldama, is not to be measured by the number and height of the summits and craters which compose it, but rather by the area which the lava from these volcanoes has covered in the form of a thin and uniform mesa. The lava from the large and small volcanoes, spreading to the north and northwest of Presas Aldama, cover an area of not less than 2500 sq. km. Several overlapping flows sustain the crests and craters of Cautivo, but the greatest spread of the lava field stretches in the form of a slightly elevated and uniform plateau, abruptly cut at its edges by erosion. To the northwest and west the lava crust almost reaches the southern slopes of the Sierra Azul, and to the north the San Rafael River washed away part of it, thus forming a wide valley whence this river reaches the sea bordering the southern end of the San Jose de las Rusias range.

As regards the secondary hills and small volcanoes, subordinate in origin to the eruptive center of Cautivo, they usually occur at the edge of the lava crust, but are also to be found on top of it. Among the small hills scattered throughout this vast desert, only a few may be mentioned, such as the cone with an open crater, known as Cerrito del Maiz, to the south near Presas Aldama; the three consecutive hills, Los Tres Hermanos, to the west of the Lagarto ranch; the cones with craters or dome-shaped hills at the edges of the lava at the foot of the Sierra Azul; and lastly, the remarkable little cones on the ranches of Bejarano, Real Viejo, El Sombrerito La Muralla, etc., etc. The majority of these basaltic cones are important as suggesting the possibility of encountering oil near them, as usually occurs in the Veracruz oil districts.

It may be of interest to state briefly some data furnished us by the study of these basaltic cones in relation to the Tertiary land formation underlying them.

The geological formation of the southern Tamaulipas coast is very uniform, both in physical constitution and in structure. The entire formation is Tertiary (Eocene). The top layers are of limestone alternating with phosphatic lime, sandstone, and thin beds of shale. This formation may be studied very well near Rancho del Cojo, on the flanks of the hills cut by erosion, forming that broad and low depression which extends between the heights of Cojo and those of Barranco ranch on the way to Gonzalez station, on the Tampico-Monterey R.R. In various other parts of that area the formation of El Cojo is found with good exposures, but the strata, as is everywhere the case on the southern Tamaulipas plain, are almost horizontal or in extensive domes, invariably having a monoclinical structure slightly dipping to the east. Below the limestone strata of the top of the formation, thin limestone beds, with shales, are found overlying the very thick shale formation, known as the Mendez shales, which has a thickness sometimes exceeding 3000 ft. (914 m.) and rests upon the San Felipe formation or upon Cretaceous limestone.

From the village of Presas Aldama to the north the country is flat over the basaltic lava or malpais for nearly 40 km. passing the ranches of Zanapa, Lagarto, and others, to near Rancho Bejarano, where the basaltic plateau ends and Eocene rocks are again exposed by the wide erosion valley of the San Rafael River.

A well-aligned series of almost isolated high mountains, with peaks broken into fantastic forms, arises from the eastern foot of this range, forming an advanced ridge the base of which is touched by the malpais. Prominent among these mountains are Jerez, Platano, Plateros, and Cerro Gordo or Alazanes, all having elevations exceeding 1500 ft. (460 m.) above sea level. A little further on from the Bejarano ranch, toward the Real Viejo farmstead, the river flows between hills at the foot of the high mountains to the west and the coast range of San José de las Rusias to the east. At the junction of the eastern hills with the low ramifications of Las Rusias range, at Lomas de la Encarnación, a broad gap divides the waters of the San Rafael river from those of the important Soto la Marina river.

Leaving the northern edge of the basaltic plateau between La Coma, Guajolote, and vicinity of the Bejarano ranches, the Tertiary shales appear throughout the valley of the San Rafael river with here and there small basaltic cones. Near certain of these cones there are some oil seepages, which suggest that in this San Rafael river valley there is a wide area of great prospective value. Even more, it is probable that the malpais of Presas Aldama, in its eastern and southern portions,

covers a large area of excellent oil ground, a prolongation of that of the San Rafael valley.

Toward the bank bordering the San Rafael river bed, or at the edge of the basaltic plateau which also bounds the valley of this river, there are excellent cuts where not only the Tertiary rocks may be observed, but also the basaltic necks in their relation to these sedimentary rocks. Among the most instructive cuts carved by the river, I would mention a low hill near Real Viejo ranch, 10 km. to the north of Bejarano ranch, and on the right bank of the San Rafael river. A wall has here been cut 20 m. high in the Tertiary shales, at the same time cutting the basaltic hill rising from the river bed to a height of 60 m. This wall plainly shows the contact between the lava and the shales, clearly marking the line of separation between these rocks. The Mendez beds, made of yellow and red shales intercalated with fine-grained reddish sandstone, in slight undulations, show a gentle uplift at the junction with the basaltic rock. Near

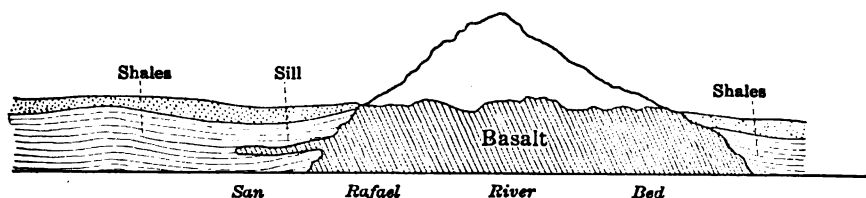


FIG. 2.—REAL VIEJO LAVA PLUG AND SURROUNDING SHALES SHOWING SLIGHT MOVEMENT OF THE SHALES UPWARD AT THE CONTACT WITH THE LAVA, AND SOME METAMORPHISM. A SMALL SILL IS NOTICED IN THE ILLUSTRATION.

this lava are some layers of shale metamorphosed into a hard schistose rock resembling flint. This metamorphism, produced by heat upon contact with the lava, is commonly found in the Veracruz oil fields where there are basaltic cones. We have seen this at Juan Casiano, La Pez, Cerro Azul and at many other places on that coast. A sill about 4 ft. (1.2 m.) thick of lava from the Real Viejo hill enters into the shales, and though this sill is not very long in the cut, it must extend much farther in places which are not visible. These lava intrusions in the form of sills in the shale formation of our oil lands are more frequent than is generally believed, and many drillers are familiar with the appearance of these lava strata in certain oil districts, even at considerable depths and at great distances from basaltic plugs.

This cut of the San Rafael river in the Real Viejo ranch illustrates various important facts to which I would draw attention. First, the sedimentary strata, upon contact with a basaltic neck, are slightly moved upward with the lava plug. Second, a slight metamorphism of the sedimentary rock occurs at its contact with the lava, due to heat. Third, the lava intrudes sills in sedimentary rocks.

On various occasions, I have already stated that plugs of lava traversing the Tertiary strata of the Gulf Coast oil fields do not perceptibly move those strata, and we take as our reason for this belief the observation of what happens in the explosive craters or *xalapascos* to which type many of the diminutive volcanoes of our eastern coast belong. Our observation is opposed to the statements of Garfias and Hawley in a recent article¹ in which the authors, on the strength of observations by Geikie and other writers, maintain that a synclinal movement of the sedimentary rocks takes place around the necks in our oil lands, and that this synclinal curve, together with other phenomena which they try to explain, facilitates accumulations of petroleum in the vicinity of the necks. This phenomenon might occur, but it is not fully proved in our oil fields. Whereas we continue to assert the almost immovable position or a gentle uplift of sedimentary rocks around the neck; the formation of broken zones at the contact of the lava and the sedimentary rocks, greater at some places than at others; and lastly, the solution of sedimentary material by the lavas and hot waters, gases, and vapors, all determining the formation of extensive hollow or porous spaces very recently filled with liquid hydrocarbons. The roots of the plugs of lava, ramified like those of a plant, have served as channels to bring the mineral oil to the hollow or porous spaces prepared during the appearance of the lava plugs. It also frequently happens that large accumulations of mineral oil, when they come in limestone subjacent to the Mendez shales and San Felipe formation, fill cavities in these limestones which have been caused exclusively by circulating waters without the help of any volcanic phenomena. In the Pánuco district it has happened that, while drilling a hard limestone, suddenly the drill has been lost in a big cave.

If oil has sometimes accumulated in old hollow spaces made by water circulation in the limestone, there is room for the belief that the slight upheaval and breaking caused in limestone by the effect of explosions, or by the sudden passage of lava, has produced fractures which, even at a great distance, may facilitate the communication between the drill holes and an oil seam, so the connection between oil and volcanic phenomenon is purely mechanical.

In front of the Real Viejo ranch, the San Rafael river bed passes at the foot of a low hill, called Sombrerito, formed at its base of shales and sandstones, a continuation of the Real Viejo Eocene shales. Higher up, shales with a greater number of thin limestone layers are seen, then the cavernous limestone of the Cojo formation. Erosion has respected there these top formations, due to a thick lava capping with a ruined

¹ Funnel and Anticlinal Ring Structure Associated with Igneous Intrusions in the Mexican Oil Fields. *Bulletin* No. 128 (August, 1917), 1147.

crater which forms a small indent. Between the basaltic lava and the limestone, on the northwest slope of this hill, there is a small oil seepage which is carried away by waters of the arroyo during the rainy season.

I have already said that the ample valley of the San Rafael east of Real Viejo and Bejarano is a most promising field for the occurrence of mineral oil. The existence of oil seepages at various points in the wide lava field of Presas Aldama indicates that this oil region is very extensive, and that undoubtedly the malpais conceals good ground which, but for the lava crust, would show oil seepages.

At Jobo ranch in the eastern part of the malpais, at no great distance from the main mass of Cautivo Mountain, a *chapopote* seepage appears through thick lava. To the southeast of Jobo, toward the edge of the lava field, are other seepages at Sabino ranch.

Undoubtedly, even the good Mexican oil lands, far from the centers of actual exploitation, to become productive require assiduous and detailed geological studies, drilling and exploration, implying a considerable investment.

Review of the Coal Situation of the World

Discussion of the paper of GEORGE S. RICE, presented at the New York meeting, February, 1918, and printed in *Bulletin* No. 133, January, 1918, pp. 131 to 141.

GEORGE S. RICE (written discussion*).—An interesting and important question arose during the coal famine of last winter as to whether the development of new mines should be discouraged on account of the need of labor for the necessary construction and development work at a time of scarcity of labor, more especially as there was an apparent over-capacity of existing mines. The question was referred to the author for his comments, which led to the study of the statistics. The essential results of this study are indicated on the accompanying chart, which illustrates, among other things, the increase in production or consumption, and the estimated maximum production capacity of the bituminous and sub-bituminous mines of the United States. The curves shown are based on data published in the "Mineral Resources" of the United States Geological Survey, and cover the period from 1900 to 1916 inclusive.

The following curves have been drawn from the data secured:

1. Average number of days that the mines worked.
2. Yearly total production of bituminous and sub-bituminous mines.
- 2a. Yearly production of machine-mined coal.
3. Average annual production, equivalent to consumption, for a period of 17 years.
4. Number of coal mine employees each year.
5. Estimated capacity of mines, on basis of 300 working days in the year.
6. Estimated drop in capacity if no new mines are opened.

Considering these curves and the data from which they were constructed:

It will be noted that the average number of days the miners worked varied from 193 in 1908 to 234 in 1900, the average being 217. The causes for so many idle days out of the possible total number of working days in the year are well known, namely: (a) Lack of business; (b) lack of cars.

Taking the country as a whole, (a) is the important factor, which might otherwise be expressed as being an excess of productive capacity.

The yearly production of the mines, which is practically synonymous with consumption, has shown a steady increase, with a few set-backs. An average line has been struck which indicates that the average annual increase of production has been 18 million short tons (16,330,000 metric tons).

* Received Apr. 4, 1918.

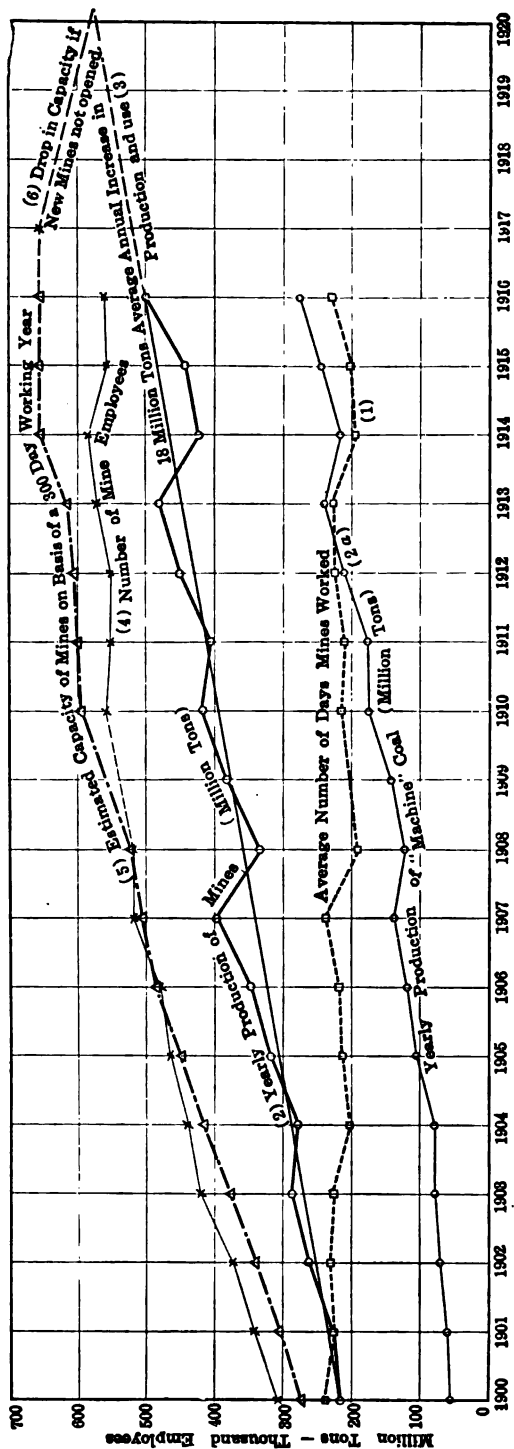


CHART ILLUSTRATING ANNUAL INCREASE IN PRODUCTION OR CONSUMPTION, ESTIMATED CAPACITY OF MINES, AND WORKING PRODUCTIVITY OF EMPLOYEES IN THE BITUMINOUS AND SUB-BITUMINOUS MINES OF THE UNITED STATES—ALSO SHOWING DROP IN CAPACITY BELOW CONSUMPTION IF NEW MINES ARE NOT OPENED.

(Production and labor figures from U. S. Geological Survey's "Mineral Resources.")

The number of employees steadily increased until 1910, then for the succeeding 6 years there was practically no increase. Fortunately, however, there has been a steady increase in the individual daily output of the bituminous and sub-bituminous mine employees, from a low point of 2.94 tons per day in 1901 to 3.91 tons in 1915. There was an insignificant falling-off to 3.89 tons in 1916. This increase in the individual capacity is unquestionably due to the greater introduction of under-cutting machines and labor-saving devices.

Statistics of Bituminous Production in the United States. (Tons of 2000 lb.)

Year	Days Worked	Men Employed	Tons per Man-day	Total Production, Million Tons	Machine-mined Coal, Million Tons	Estimated Capacity,* Million Tons
1900	234	304,375	2.98	212	53	271
1901	225	340,235	2.94	226	58	301
1902	230	370,056	3.06	260	70	339
1903	225	415,777	3.02	283	78	378
1904	202	437,832	3.15	278	79	413
1905	211	460,629	3.24	315	103	449
1906	213	478,425	3.36	342	119	482
1907	234	513,258	3.29	394	139	505
1908	193	516,264	3.34	333	123	518
1909	(a)	(a)	(a)	380	142	(a)
1910	217	555,533	3.46	417	174	593
1911	211	549,775	3.50	405	178	595
1912	223	548,632	3.68	450	211	606
1913	232	571,882	3.61	478	242	618
1914	195	583,506	3.71	423	218	652
1915	203	557,456	3.91	443	243	655
1916	230	561,102	3.89	503	284	656

(a) Statistics not collected for the year 1909.

Curve (2a), showing the production of machine-mined coal, indicates a steady increase in the proportion of the total production. Whether or not further increases per mine employee may be expected remains an unsettled question, because the alleged drop in labor efficiency, due to tremendous increase in the unit prices paid labor, if true, may prevent future increase in daily output per employee through further introduction of labor-saving machinery and in this way curtail the total production until additional miners and laborers are available.

In estimating the maximum capacity of the mines in which labor and mechanical equipment are factors, it is possible, assuming ample transportation facilities, to work the mines 300 days in the year. Some well situated mines, especially mines owned and operated by railroads for their fuel supply, have done better than this, 310 days or over being reported. On the assumption that the rate of output for the days actually

* If mines worked 300 days at same rate.

worked could be maintained for the remainder of the 300-day working year, curve (5) has been constructed. This indicates that the total possible productive capacity of the mines of the country has steadily risen at a rapid rate of about 32 million tons annually, until 1910. From then to 1914 the rate fell to 15 million tons increase, and for the years 1914, 1915, and 1916 it was practically stationary. It has been assumed that it was stationary in 1917.

An attempt has been made to obtain figures for the number of mines which are worked out and abandoned each year. The statistics gathered have been considered unreliable. The author, in order to arrive at certain approximate results, has had to make an assumption of the average life-time of a bituminous coal mine. From his own experience, and that of other mining engineers whom he has consulted, the assumption has been made that the average life-time is 20 years. If this is true, then one-twentieth of the mines are worked out and abandoned each year.

The Geological Survey compiled the number of mines, and the outputs for different sized mines, from 1909 to 1914 inclusive ("Mineral Resources"). This compilation shows that the output of mines producing over 10,000 tons annually was over 98 per cent. of the total production of the United States. The number of such mines and their output is as follows:

Year	Number of Mines with Outputs over 10,000 Tons Annually	Total Output, Million Tons	Average Out- put per Mine Tons
1909.....	3721	371.6	100,000
1910.....	3909	419.7	107,000
1911.....	3810	397.9	104,000
1912.....	3977	443.0	111,000
1913.....	4027	471.3	117,000
1914.....	3916	415.3	106,000

In 1913 (the highest figure), if 5 per cent. of the mines were worked out, then 201 mines, producing 23 million tons, ceased production.

On the basis of the average annual output as indicated by curve (3), if extended to 1917, the figure for the total output is 520 million tons, 5 per cent. of which is 25 million tons. This amount must be made up by the opening and development of new mines, in addition to which there must be enough other new developments to provide for the natural increase in consumption, which it has been shown has steadily increased for 20 years at an average rate of 18 million tons per annum (curve 3). In other words, enough new mines to produce 43 million tons must be opened in 1918, and increasingly more during succeeding years to maintain a margin of capacity over consumption. This means that about 400 new mines, on the basis of previous assumptions, should be opened in 1918.

Assuming that the maximum capacity of all the mines on a 300-day basis for 1917 was unchanged from 1916 (the capacity for 1914 to 1916 inclusive apparently being stationary), and assuming that no new mines were opened after Dec. 31, 1917, then the line (6), which indicates a drop in capacity of 25 million tons per annum, would intersect the extended average consumption line (3) in 3 years, or at the end of 1920. As a matter of fact, it is probable that the estimated maximum capacity indicated on the chart could never be quite reached, on account of transportation difficulties. Hence, if no new mines were opened after Dec. 31, 1917, it is probable that inside of two years, or by the end of 1919, the consumption would have to be curtailed by reason of the estimated limitation of capacity of mines now shipping.

Fortunately, however, the situation was appreciated, and it is understood by the author that no governmental restrictions have been placed on opening new mines.

The Briquetting of Anthracite Coal

Discussion of the paper of W. P. FREY, presented at the New York meeting, February, 1918, and printed in *Bulletin* No. 133, January, 1918, pp. 143 to 149.

J. B. MCGRAW, New York, N. Y. (written discussion*).—In Mr. Burke Baker's description of the process of the American Briquet Co.,¹ he speaks only of the attractive features, but every process which uses a compound or emulsified binder has certain undesirable features which must be considered.

In making an emulsion, the success of which depends upon the introduction of the various ingredients at certain fixed temperatures and the complete intermixing of a soluble solution with an oil which has absolutely no affinity for it, considerable difficulty is found in keeping the various factors in strict accordance with the formula. To serve its purpose properly or, in other words, to be right for easy mixing with the coal, it should be of a certain predetermined density. Among the controlling factors of this are the proportion of moisture contained and the temperature of the oil when introduced. If the latter is higher than intended, a greater proportion of moisture will be evaporated than is proper, and if the oil is not sufficiently hot the process of emulsification is retarded.

These various factors can be controlled with more or less certainty when working in a laboratory or in a small experimental way, but when it is attempted on a large commercial scale, certain obstacles not otherwise apparent are likely to be encountered.

* Received April 4, 1918.

¹ *Bulletin* No. 135 (March, 1918), 700.

Another feature which does not appeal to the experienced briquetting engineer is the necessity of drying or baking the briquettes before they can be shipped. It has been found by past experience that the problem of maintaining the necessary uniform temperature throughout an oven of the size required is extremely difficult. Unlike textiles or loosely laid pulverulent materials, such as iron ore and the like, briquettes, because of their greater density, must be exposed to the drying temperature a greater length of time. If they could be dried in batches it would be a simpler proposition, but as the oven must be of a continuous operating type, in keeping with the rest of the plant, the difficulties are increased.

It is true that a certain degree of success has been attained in operations on a small scale, but it is notable that in the entire history of briquetting in this country no process which requires the drying of briquettes has ever been developed on a large scale.

In the case of briquettes made with a starch binder, it is necessary not only to drive off the moisture but actually to bake them in order to convert the starch into coke before they become weather proof. This requirement further complicates the problem.

A briquette from which 6 per cent. or more of moisture has been dried out cannot have the strength or density to resist the shocks of ordinary handling which it should have. If properly mixed, the moisture will have been distributed throughout its mass in infinitesimal globules, and after this is evaporated the structure will be porous and very much weakened.

To be a commercial success, a briquetting process should be as simple as possible and the product should be strong and tough enough to withstand the same treatment in loading and unloading as ordinary anthracite coal, with little or no breakage.

The failure of many briquetting enterprises which started out under apparently favorable conditions can be laid to the presence of one or more complicated features which failed to work out in practice as intended.

Methods of Valuing Oil Lands

Discussion of the paper of M. L. REQUA, presented at the New York meeting, February, 1918, and printed in *Bulletin* No. 134, February, 1918, pp. 409 to 428.

EUGENE WESLEY SHAW, * Washington, D. C. (written discussion †).—Mr. Requa's subject is one of great economic importance, yet relatively new, and he has been able to combine extensive practical experience with the talent of grasping the broad features of a problem that has many discordant details.

* Geologist, U. S. Geological Survey.

† Received Apr. 1, 1918.

After examining Mr. Requa's paper with some care, I would like to ask a few questions about headings and entries in tables. For example, on page 412, why are there two tables together with the same heading in different forms? What does "Sheet No. 1" and "Sheet No. 2" refer to? I should like to know if account is taken of days when the well is out of commission, if "first year" begins with the first of the first year or of the first month, or the first day of the well's life—in other words, the actual significance of "number of days." Other questions arise concerning other tables.

I have been much impressed by several conclusions set forth or implied by the paper.

First of all, the total yield of an average well in several California fields is about five times its initial production times 365; that is, it yields roughly 1800 times as much in its lifetime as it does in the first day. Moreover, there is a remarkable similarity among the average wells for different fields, the minimum yielding about 1500 times the first day's yield and the maximum roughly 2000 times.

The rate of decline of the average well in the fields discussed is not uniform, as, of course, is generally realized, but itself declines and at a rate that shows a gradual decrease as the well becomes older. The curve for the average well has a relatively sharp flexure from the fifth to the ninth year, or while the well is declining from a third of its initial yield to a sixth. Although the observed data do not extend beyond this period, and in some fields they do not extend to it, the range of possibilities is rather narrow and the extrapolation of the curve is done without danger of great error.

The similarity of the average curves is especially striking when compared with the data on which they are founded. The individual wells seem to show wide variation and much irregularity. In particular, although the average curves show very rapid decline in the first and second years, the figures in the tables (page 411) indicate that many wells make even more the second year than the first, and perhaps that most wells reach this maximum production on some day considerably after the well is brought in, so that the decline is not continuous from the beginning.

Perhaps it is a personal predilection, but I like to see an ideal curve as mathematically simple and regular as possible. I believe, however, that there is a sound reason for so constructing ideal curves, this being that errors are thus reduced to a minimum. To put it more concretely, suppose an ideal decline curve is to be constructed for the average well of a field containing many wells, only a part of which have recorded production figures. If the records of the known wells are averaged, and the average is plotted, there will be irregularities, though, due to the averaging, these irregularities will be of lesser degree than those of the

curves for the individual wells. The best guess at the curve that could be constructed, if the records of all wells were known, is to be made by smoothing out the irregularities in the average for the known wells according to some law—in other words, attempting to find the average curve that would be determined if there were an infinite number of wells, and records of all had been kept.

Mr. Requa's ideal decline curve (see table on page 413) is not of this sort. In lopping off irregularities he comes to a series of values that are not definable in a simple mathematical formula, and although the values may approximate both the average of the observed yields, and the ideal average, or that of an infinite number of wells, they do not represent either of these curves. Steep-sided and narrow departures from regularity are eliminated, but broad irregularities are left in. The curve for an infinite number of wells would in all probability show a geometric decline, though it might involve a progressive increase in the decline of the decline in rate of production, or something even more complex. A curve with a relatively simple formula, that fits as closely as may be the observed values, is more likely to be the ideal curve of decline that all wells tend to approach than any other single line that can be drawn—certainly more so than one having an arithmetic decrease in the rate of decline, changing abruptly to a fixed decline. On the other hand, the arithmetic series may be as close an approximation as is needed for most purposes and the integral feature makes it more useful than if fractions were involved.

A formula that seems to me applicable to the decline of individual wells is

$$y = a \times b^{x^c}$$

and it also seems probable, on theoretical grounds, that this formula will represent rather closely not only the decline of wells but of pools and groups of pools, the values of the constants, of course, being different for each case. For the decline in the production of oil in Illinois, the formula may be written

$$y = 28,601,000 \times 0.9^{x^{0.9}}$$

the values of the constants here given being only approximate and the large whole number being the production of the State in 1912, the beginning of pronounced decline. If $c = 0$, y is a constant and the curve is a straight line parallel to the X axis; if c is less than 1, the curve approaches both axes indefinitely; if c is greater than 1, the curve has a double flexure cutting the X axis at right angles and approaching the Y axis indefinitely; if $c = 1$, the curve straightens as it approaches the X axis, crossing it at an acute angle and approaches the Y axis indefinitely.

Fig. 2 of the paper presents a number of relations of much interest,

though, as in Fig. 1, the significance of some features is not quite clear. Presumably the plotted points represent averages of observed values, for they show irregularity in spacing and alignment, and yet not nearly so much irregularity as individual wells would show. In any case, the total production curves are almost straight lines and indicate that the ultimate yield of a 20-bbl. well will be twice that of a 10-bbl. well, half that of a 40-bbl. well, and so on to the limits of the data, a 100-bbl. Santa Maria(?) well yielding in the long run 160,000 bbl., whereas a 5-bbl. well in this field yields about one-twentieth as much, or 8000 bbl. I believe that in the oil fields with which I am most familiar this relation would not hold, but still a positive statement cannot be made because the recorded data are so scant, particularly as regards the later history of wells, most of the wells with performance records being as yet only in their prime.

It is interesting to study the problem theoretically, though the results may be of little practical value. Apparently there are four main factors controlling the initial yield of a well: (1) thickness of pay; (2) size of pores and any other cavities in the reservoir, both individually and collectively; (3) pressure; (4) size of bottom of well. Perhaps quality of equipment and skill of drillers should be included in this list, but let them be classed temporarily as minor factors along with viscosity of oil, shape of pores, cementation of sand, etc. The rate of yield throughout the life of the well depends on these and a number of other factors, such as any condition leading to clogging of the sand pores, or the tubing, the ability of water or some other fluid to follow up and take the place of the oil as it moves from the sand to the well ("dry sand" exponents to the contrary notwithstanding), the amount and distribution of gas (in solution, in small or large pools, in or above the oil), etc. The ultimate yield must depend principally on the volume of that portion of the reservoir from which the well can draw (controlled by character of sand, spacing of wells, ability of adjacent beds to yield water, etc.), and the percentage of recovery—a highly important but little known element, the variations in which may, in the lack of information to the contrary, be assumed to balance when any large number of wells is involved.

Now an inspection of this preliminary analysis, bearing in mind the general laws governing the flow of liquids and gases through capillary and larger tubes, leads one to the following presumptions concerning the ultimate yields of, for example, a 200-bbl. well and a 100-bbl. well. If the greater initial yield of the 200-bbl. well is due to greater thickness of pay, other factors being equal or in balance, its ultimate yield should be somewhat more than twice as much, because, on account of disproportionate increase in friction, a little more than twice the cross-section area of the oil stream would be necessary to double the output. With wells no larger than a few hundred barrels, this difference is probably negligible.

If the greater yield of the 200-bbl. well is due to greater diameter of pores, but not greater amount of pore space, the ultimate yield should be greater only in proportion as the percentage of recovery is greater. On the other hand, if the aggregate volume of pores is greater in the larger well, but their size not essentially different, the case would be similar to, if not the same as, that of greater thickness of pay.

If pressure is the sole cause of the difference in initial yield of the two wells, the ultimate yields should not differ greatly, and a similar inference must be drawn concerning the fourth important factor—size of bottom of well.

I would, therefore, expect, both from theoretical considerations and from the performance of wells with which I am more or less well acquainted, that, in general, a 200-bbl. well would hardly yield twice as much as a 100-bbl. well, and that a 10,000-bbl. well would be very unlikely to yield a thousand times as much in the end as a 10-bbl. well. On the other hand, in a single field of fairly uniform nature and perhaps a single main producing sand, it is quite conceivable that differences of initial yield are due much more to differences in thickness of pay and volume of pore space than to variations in average diameter of pores, pressure, or size of well bottoms, and hence that the ultimate yield of the wells might be roughly proportionate to their initial yield. Although this is admitted, I am rather strongly of the opinion that in the fields of Pennsylvania, West Virginia, Ohio, Kentucky, Illinois, Texas, and Louisiana, that I have studied, the ultimate production of the large wells falls short of being proportional to their initial capacities. Lewis and Beal find that in the Osage Reservation the well that has a big output for the first year has a much sharper decline than the small well (*Bulletin* 134, p. 487).

There are many other interesting and to me more or less surprising things in Mr. Requa's paper. I would have expected the curves in Fig. 4 to show that after a depth of 2500 or 3000 ft. had been reached, the time required to drill 100 ft. would increase, and I would expect the "average cost" curves in Fig. 8 to show an increase in cost per foot with depth, instead of uniformity from 1200 or 1500 ft. to about 3000 ft., beyond which there is an abrupt decrease in cost per foot. I am also rather surprised that all the profit curves in Fig. 8 drop to zero at 20-bbl. initial production, implying that a 21-bbl. well might return 35 c. a barrel on its output—as much as a 300-bbl. well could—but a 19-bbl. well would be unprofitable.

It is worthy of note that Mr. Requa's "methods of valuing oil lands" are strictly technologic, the main factors taken into account being production records and cost statistics, and they do not take into consideration geologic facts such as thickness of pay, size, shape, and aggregate volume of pores, gas in the sand, water that may get into the sand from one side

of the pool or above or below, character of other strata in the region, etc. I believe that there are a good many geologic features which can be taken into consideration to advantage in the valuation of oil lands. The importance of each varies from place to place and perhaps several may be ignored without error, in appraising a property in the middle of a well drilled field. I believe also, as I pointed out in *Bulletin* 629 of the United States Geological Survey, that the doctrine of chances has much value in some places. Indeed, it has long played, incognito, a part in the opinions of experienced men as to the values of oil lands, and it may as well be recognized by its proper name and occasionally used mathematically.

Measurements of pressure are of greater value in appraising gas lands, but can be used to advantage, I believe, also for oil, especially where there is considerable gas with the oil. The comparison of closed pressure decline and volume produced, perhaps first outlined in the report referred to above, may be of considerable value. If a well yielding gassy oil has a closed pressure of 1000 lb. at one date and, after yielding a measured but not large quantity of gas and oil, drops to 100 lb., the quantity remaining in the ground is presumably much smaller than if, with the same output, the pressure had dropped only to 500 lb. Of course, in the absence of gas this side light could not be used.

Some New Methods for Estimating the Future Production of Oil Wells

Discussion of the paper of J. O. LEWIS and CARL H. BEAL, presented at the New York meeting, February, 1918, and printed in *Bulletin* No. 134, February, 1918, pp. 477 to 504.

EUGENE WESLEY SHAW,* Washington, D. C. (written discussion†).—Studies of the probable future production of oil wells and fields—particularly those in the nature of the recent work by Lewis and Beal, having the object of increasing the percentage of recovery—rank, in both practical and theoretic value, very high, if indeed they do not outrank all other petroleum investigations except structural surveys. Even such surveys, although saving untold millions that might have been spent in prospecting unpromising territory, may have less ultimate value than generally supposed, for it may perhaps be argued that much if not most of the condemned territory will sooner or later be tested—some is already productive—and the most that can be rightly claimed is the recovery of cream first; also that the consumption of the richest portions first cannot be extenuated, as it might with some resources, on the ground that if the best is not taken now it will deteriorate.

* Geologist, U. S. Geological Survey.

† Received Apr. 1, 1918.

On the other hand, he who can raise the fraction of petroleum recovery by 1 per cent. has added millions to our national resources, just as he does who saves oil from fire, the only difference being that possibly the oil left in the ground may, in a century or two, collect and form a new pool.

I had the opportunity of reading the present paper by Lewis and Beal in manuscript, and I felt that I should like to see performance records of individual representative wells. Unfortunately, such records seem not to have been kept in the Osage and Nowata fields, which furnish most of the foundation of this paper. Although some of the relations set forth seem sufficiently obvious to need no corroborative data, it seems to me that for both scientific and economic reasons it is highly desirable to record the monthly yields of individual wells and, until a good sized available supply of such data is accumulated, to publish the details. Some readers will, without failing to appreciate the personal backing of the conclusions, wish to know the precise nature of the foundation and to have the data for further analysis.

The so-called saturation or pore-space method of estimating unrecovered oil is not, it seems to me, of such small value as Lewis and Beal and others believe. I have used it with satisfactory results in a number of fields, and believe that, with recognition of its limitations, it has a good deal of value, particularly where standard tools are used, and fairly accurate information can be gained concerning not only the thickness and lateral extent of the pay, but water and "dry" streaks in the pay, size of pores, and also methods of recovery. Where, because of lack of recorded data, or for any other reason, other methods are inapplicable, the pore-space method commonly gives results that, I believe, are far better than none at all, and elsewhere it can be used as a valuable side light, corroborating or throwing doubt, as the case may be.

Fig. 4 and 5 of the paper are of much interest and worth careful study. In the first place, it seems to me that, unless the relations are clearly indicated, it is somewhat confusing to find two sets of curves with different scales plotted on the same area, the scale for one being shown on one side and for the other on the opposite side of the diagram. Also, the words "per well" seem to be needed after "total production."

Certain facts lead one to ask, Just how well established are the form and position of the curves in Fig. 4 and 5? These facts are that the position of the points is to a degree inferential (the extent not being apparent) because some of the properties are presumably still producing, so that their ultimate yield is a matter of estimate; that some of the points plotted fall outside the area between the maximum and minimum curves; that the statement is made on page 492 that "judgment must be used in selecting and applying the records;" that the two curves approach each other in the direction that the observed data become less numerous, and

in the direction of increase in per cent. of past production as compared with total production; and that the dots do not become much more numerous toward the average curve.

It should be borne in mind that the curves are sketched, and hence that two persons would not draw them just alike. It is evident, also, that a field of small extent and uniform conditions, even though divided into many properties, will give a denser pattern of dots than a large field of various and varying sands and other irregularities. Also, a field each of whose properties is quickly drilled up will give a different diagram from one where the leases are only gradually drilled.

Concerning the general features of the diagrams and the conclusions drawn from them, there can be little doubt, but for the general application of the method there appear to be certain necessary conditions which can not always be met. There would seem to be the following requisites for using the curves in estimating future production: (1) The field should be well along in development, and production records of many properties should be available, so that the curves can be constructed; (2) the property in question should be a year old—and that means that it has produced from one-fifth to two-thirds of all that it will ever produce—so that its position on the diagram can be plotted; (3) recognition of the probable error.

This probable error is really quite large, especially for wells of small initial production, perhaps because a smaller fraction of the total production of such wells is yielded the first year. If one has a drilled-up lease in the Osage that has been producing a year at an average rate of 10 bbl. per well per day, or 3650 bbl. per well for the year, he may expect to get in the future from 1.6 to 5.8 times as much—a rather wide range of possibilities—the best guess or mean being 3.2 times. It will be noted that 3.2 is below the arithmetic mean of the two extremes, and from the figure it will be seen that it is considerably below the algebraic sum of the points plotted above and below the mean. If his wells have averaged 100 bbl. a day for a year, instead of 10 bbl., the quantity that he may expect still to recover will be 1.2 times what the lease has already yielded, but he may get as little as 0.6 or as much as 2.1 times the past production.

The question naturally arises, How much better are these estimates than the guesses of experienced operators? Could not almost any good oil man make, at the end of a year of production of one of his leases, a guess at the future production of that lease which, barring accidents and unusual features, as is done with the "appraisal curve" method, could be depended upon as being not many fold in error? And if the wells had averaged large, so that a larger fraction of the ultimate output had already been produced, might not his guess be accordingly close to the true figure?

Qualitatively, the diagrams of Lewis and Beal have certainly a two-

fold value. For men of lesser experience they tend to make it possible to estimate future production, presenting in concrete, available from the data concerning two fields, and they make available a new method of attack for other fields where there are enough recorded data. Second, for men of greater experience, they furnish material for better estimates and a better understanding of the probable error.

Apparently the practical oil producer, who makes estimates without itemizing the basis in detail, has the advantage in two respects; he can use the details in the rate of decline of the property, and, if it has been producing for more than a year, he can use the more nearly complete record of production. Also, he may be acquainted with idiosyncracies of individual wells that tend properly to modify estimates of future production. As noted above, the larger the fraction that has already been produced, the better the estimate of future production by whatever method.

Perhaps the most striking conclusion of the paper is that "wells of equal yield will have approximately the same future productions regardless of the ages of the wells" (page 504). This seems to be in disagreement with the individual well curves and conclusions presented in Mr. Requa's paper (*Bulletin* 134, pp. 409-428), with production curves of wells in other fields so far as recorded, with the general impression that has given rise to the expression "settled production," and with theoretical considerations concerning the performance of a well yielding a liquid and a gas from the pores of a sand where they have been under high pressure. One wonders, therefore, if a similar conclusion would have seemed justifiable if records of individual wells had been available. In other words, if it does not depend upon the overlapping of individual curves in the group or property curve, thus tending to reduce the steepness of the usually sharp initial decline. With the exception of wells that produce from unconsolidated sands, of which the production commonly increases for a time, the general rule is surely beyond question that the yield of a well falls off more rapidly at first, not only in number of barrels but in per cent., than it does later. The records of individual performance that are available to me come from several widely separated fields, and do not seem to bear out either the conclusion of Lewis and Beal that future production is independent of age but depends wholly on present production, nor that of Requa that the ultimate production varies directly as the initial production.

Some Structures in Steel Fusion Welds

Discussion of the paper of S. W. MILLER, presented at the New York meeting, February, 1918, and printed in *Bulletin* No. 134, February, 1918, pp. 391 to 408.

GEORGE F. COMSTOCK,* Niagara Falls, N. Y. (written discussion†).— I have recently had the pleasure of reading Mr. Miller's interesting paper, and would like to call attention to a reference to this subject which apparently has escaped his notice. It is an abstract of a German research on the subject of nitrogen in steel, and appeared in the *Iron Age* of Feb. 17, 1916, page 432. Photomicrographs of needles such as Mr. Miller found in his welds are given, and their identity is discussed. The conclusion reached is that the needles are slip lines due to the brittleness of the ferrite crystals caused by their absorption of nitrogen. The deformation necessary to develop the slips is supposed to be accomplished either in cutting or polishing the microsections or by cooling strains after welding. It seems very reasonable to expect that nitrogen would be absorbed by steel in either electric or oxy-acetylene welding, and the reference I have mentioned gives instances of many unusual structures resulting from the presence of considerable nitrogen with carbon in steel. But the nitrogen is rapidly given off from steel by ordinary annealing in air, hydrogen or vacuum, and this would explain the disappearance of Mr. Miller's needles after annealing. I think the conclusion that the needles are cementite might well be revised in view of this German work on nitrogen.

Grain-size Inheritance in Iron and Carbon Steel

Discussion of the paper of ZAY JEFFRIES, presented at the New York meeting, February, 1918, and printed in *Bulletin* No. 131, November, 1917, pp. 1883 to 1899.

SAMUEL T. HOYT,‡ Minneapolis, Minn. (written discussion||).— The subject of grain inheritance in iron and steel is apparently one which can be considered from the point of view of the two laws governing the rate of formation of crystal nuclei and the linear velocity of crystallization, which have been investigated by Tammann and collaborators, and of the additional law of coalescence. According to the work of Tammann, both the nuclei number, which is taken to be the number of crystal nuclei to form per unit volume per unit time, and the linear velocity of crystalli-

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† Received Mar. 30, 1918.

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|| Received Apr. 1, 1918.

zation vary with the temperature or degree of supercooling. Therefore, according to the rate of cooling, we may have different absolute and relative values of these two factors governing the formation of the new phase, or phases, as the case may be. If the maximum value for the linear velocity is obtained just under the transformation point, but above the temperature corresponding to the maximum nuclei number, slow cooling produces a larger grain size than rapid cooling. On the other hand, if the linear velocity does not attain appreciable magnitude until a temperature below that corresponding to the maximum nuclei number, we may have the reverse action, in which case rapid cooling produces coarser grain than slow cooling. The former of these two cases is the more common, as it is well known that rapid cooling ordinarily produces the finer grain size, although the rate of cooling itself has but the secondary effect of determining the actual values of the nuclei number and linear velocity which govern the crystallization of the new phase. It would then seem necessary to consider here the nuclei number and linear velocity as primary factors and the rate of cooling, chemical composition, chemical constitution, and physical condition, as secondary factors.

It is quite evident that pure iron recrystallizes at A_3 ; i.e., crystal nuclei form in accordance with the momentary nuclei number and these crystal nuclei grow into crystallites of the new phase at a rate which is commensurate with the momentary velocity of crystallization, both of which may actually vary during the transformation. Only in case the grain size were smaller than the "equilibrium grain size" would coalescence play an important rôle in governing the grain size.¹ According to this, we would not expect an inheritance of grain size in pure iron, nor in the alloys of iron and carbon containing up to 0.3 per cent. C, the structure of which is largely determined by the structure of ferrite. In no case need we consider that one crystallite of γ iron changes into one crystallite of α iron, or *vice versa*; not even grain-size inheritance would indicate this.

In the case of the hyper- and hypo-eutectoid steels, grain-size inheritance is the natural consequence of the segregation of the ferrite and cementite and the lack of sufficient material for the formation of crystallites of normal size, as is true when the carbon is below 0.3 per cent. The formation of pearlite "colonies," while subject to the same laws, in common with the formation of eutectics and eutectoids in general, to the writer's knowledge, has not been worked out satisfactorily as yet. This is due principally to our lack of knowledge as to the mechanism of the process. However, it seems perfectly clear that the size of the individual colony will be different from the size of the austenite

¹ I assume Professor Jeffries' definition of equilibrium grain size would be that grain size which is very readily assumed at any temperature but which is not very readily increased by further annealing.

grain just as α iron will have a different grain size from γ iron. On heating, the conditions are somewhat different, in that material from two different sources (ferrite and cementite) is used in the production of the new constituent, the solid solution. Here again our knowledge of the mechanism of the process is somewhat deficient, but it seems that the austenite to form is excessively fine grained (Hanemann). This indicates that an excessively large number of austenite crystallites (for it seems necessary to assume that this austenite is crystalline) form from the pearlite, which grow in size by coalescence in the case of eutectoid steel, or by coalescence and the dissolution of ferrite and cementite in the case of hypo- and hyper-eutectoid steels. In the latter case, growth by coalescence is enhanced by the rising temperature.

As an attempt to explain the subject matter and questions raised in the second paragraph on page 1895, the following is advanced. The formation of ferrite particles in sorbite differs from the formation of ferrite crystallites in primary ferrite and in pearlite. When lamellar pearlite forms, there is evidently an appreciable velocity of crystallization, such that the nuclei readily grow to visible size. When the ferrite particles of sorbite form, the linear velocity is evidently very low, so that about all we have is the formation of a large number of ferrite particles a little larger than nuclei. Their growth, as for example in the granular pearlite, would then be due to coalescence. As to the relationship between the grains of austenite and the nuclei of the new phase, it should be remembered that the formation of nuclei is a property, not of the old-phase austenite, but of the new phase which is forming. With this in mind, it would be of interest to investigate the factors affecting the formation and growth of the transformation products.

The Crippled Soldier in Industry

Discussion of the paper of MAJOR FRANK GILBRETH, presented at the New York meeting, February, 1918, and printed in *Bulletin* No. 136, April, 1918, pp. 893 to 899.

W. O. OWEN,* Washington, D. C. (written discussion†).—Few people appear to realize that the time to reach the crippled soldier is when he is first hurt. In my own judgment, the best time to reach him is before he is hurt, by showing him what other cripples have themselves done of their own initiative, without Government support, rendering themselves self-supporting, able to bear a little bit more than their own weight, so that they may lay aside a little bit for a rainy day and some for a little fun in

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† Received Mar. 30, 1918.

life as it passes by. Then, when the time comes, he recalls these pictures and they give him hope. Give a man hope that he can teach himself, so that he can carry his own weight in competition with other men, and he will work like a digger to accomplish this end, and thus train his brain and his remaining faculties to such a degree that he is of far more value than he ever was before.

I often think of what was once said to me by "O N E BEST WAY GILBRETH," that he could see no good reason why a man might not have at least half a dozen mechanical hands in addition to his own two—all that was required was to train his mind so that his muscles would handle and coördinate these four pairs of hands.

I have a picture of a highly trained electrical engineer who has no hands, and only stumps of arms, but he makes his own mechanical drawings, and is employed by a large electrical company as an inspector of meters, training other inspectors to do this work. He rides his own bicycle to and from work, through the densest part of the traffic of one of the large cities of the United States.

An engineer is one who makes exact measurements and records the results in terms of exact measure in three dimensions of space, and the period of time, so that any well trained engineer may repeat the experiment or the mechanical performance at will, and when a new problem comes up, may apply this same exact method to the study of the solution of the new problem. Hence it is that I have felt that it was the engineer alone who could solve the problems for the cripple and help him on his way to a self-supporting life. No one is more aware of the many subdivisions of engineering than the engineering profession itself.

It is curious that the men in this great, splendid profession fail to realize that "there is a new Richmond in the field" contending for his position in the center of the sun. This man, too, experiments with material and makes record of the results of what the interaction of these materials may be in three dimensional space and in measured periods of time; it is his task to study and measure the relationship between living entities and their products, and their relations to space and time; therefore I think he may be properly classed as an engineer and take his place in this great profession of yours—a new specialty engineer—the Biological Engineer.

FRANK E. SANBORN,* Columbus, Ohio (written discussion†).—Advancement in the movement for the benefit of cripples, both of peace and of war, in this country has been given great impulse by the author of the paper. He has been preaching and teaching it for several years. We are

* Director, Industrial Arts Department, Ohio State University.

† Received, Apr. 1, 1918.

indebted to him not only for his presentation of certain phases of what should be done but also for the means, the instruments of measurement.

Before this world war the industrial nations of Europe had recognized the need of something definite for the employment of the cripples of peaceful times. The war has accentuated this need and hastened these developments already started. They are way ahead of us in this and we can learn much from them, modifying it to meet any different condition of life here.

There are some statements, perhaps axioms, which we might have in mind from the start:

Work is a blessing and not a curse.

Overwork is a curse and not a blessing. By overwork is meant that amount of work of any kind which produces so great a fatigue that it is impossible for the worker to recover his former or normal energy from week to week.

"Nothing to do" is a great curse for a well, normal person. This "nothing to do" may arise from pure laziness, from too much wealth, from lack of ambition.

Any person who has a dollar is a capitalist.

Any person who is engaged in a useful employment is a laborer.

These capitalists and laborers coexist; each is the other, always was and always will be.

The material things of life are made available to more persons as the cost of the production and distribution are lessened.

Persons have more ability to purchase as their financial return for their labor and their invested capital is increased.

The more persons there are with good financial returns the better the industries of the country.

Therefore each person should make as large an output as possible and receive as large a return as possible for it. These go hand in hand.

The object of scientific management is to put into operation ways and means to secure this result, applying all the known laws of science involved, conserving the individuals and increasing their happiness.

With these statements in mind, what shall we attempt to do for and with the crippled soldier? The crippled soldier is a crippled person; he was busy in some occupation before he laid it aside to fight as a soldier. He returns a cripple in many cases. He may be able to carry on his old work as well as before, and he may not.

Allied countries abroad have adopted the policy that the Government has the duty to perform of seeing that every crippled soldier, upon his discharge, is able to earn a living, if possible. While in the hospital, the soldiers have their attention called to the reëducation opportunities. These opportunities are for trades, arts, and professions. Each soldier is also granted a pension, on the policy of the same pension for the same

wound regardless of the man's previous position in society; the pension varies with the kind of wound. The return is not made too large, as there is no intention to support the man in idleness, if he can be made available to society; and there is no intention to reduce the amount of his pension in case he reëducates himself and makes good earnings.

This country can do no less than to adopt similar policies: reconstruction of the soldier's body, compulsory reëducation into some field of useful endeavor when necessary, public employment bureaus for placing cripples, pensions for wounds and disabilities.

These being our policies in part, how can they be carried out? Laws must be enacted by Congress and money made available for these purposes, where no authority now exists to go ahead. The soldiers belong to the Nation and the task and duty are the Nation's. The several States will aid, without doubt.

The French have called all this work with the cripple, looking toward his rehabilitation, "reëducation," subdividing it into "functional reëducation," which includes the restoration of their natural functions to the various ailing members of the body; "prosthetical reëducation," which includes the adaptation of the various artificial devices used in replacement of natural members of the body; and "professional reëducation" or vocational education, which educates and trains the man for his future vocation.

In my discussion I include the first two under the term "reconstruction" and the last under the term "reëducation." The first might, in general terms, be said to deal with the cripple "from the battlefield to the wooden leg," and the latter "from the wooden leg to the industry."

The reconstruction belongs principally to the doctor, aided somewhat by the engineer and the physical director. The doctor has the task of re-forming the body first. In restoring to man the use of limbs, muscles and faculties, many forms of therapy are utilized, as electro-therapy, mechano-therapy, orthopedic-therapy, massage, physical training. In this work the ability of the engineer will be of assistance in designing new apparatus of various kinds to meet the changing needs and conditions, and to make different tests of a physical nature.

The reëducation belongs to the engineer, assisted by the educator and the doctor. M. Leon De Paeuw in a recent book states that excellent results have been secured by the combination of a military man, who has charge of all purely administrative questions and superintends food, clothing, bedding and discipline, an engineer in charge of the technical training, an educator for general educational work, and a doctor. Where occupations pertaining to farm life and soil cultivation are taught, some technical men in these lines are naturally needed. All of these men must be of broad caliber and of sympathetic and understanding nature.

It has been found by experience to be best that the soldiers who need

reëducation shall not be discharged from the army until they are brought to the point of being able to earn a comfortable living. A short furlough home between the time when they are ready for reëducation and the time when they actually enter into it has been found good. The location of the various centers of reëducation should be considered carefully. Apparently too large a city is not desirable, and also too isolated a situation in the country.

By far the larger portion of the crippled men are able to carry on their previous occupation, some without any extra training, others with the benefit of such training have been able to occupy successfully positions superior to those they formerly held in the same industry.

In connection with the expression "crippled soldiers," we should not confine our idea of them simply to those who have lost an arm or a leg, and thus show marked outward evidence of their loss. The limbs may be present but incapacitated for their former service. Other portions of the body may have suffered injury so that they are incapable of full duty.

For the benefit of all, it is necessary that all crippled soldiers secure occupation. To this end a National Employment Bureau, State employment bureaus, and perhaps city employment bureaus should be established and plans formulated so that they will work together harmoniously. They must have classified knowledge of the different industries and trades, including all the subdivisions, so arranged that they will be able to say to a given man with a given handicap that certain positions could be filled by him and certain ones could not, of the number which he might find himself inclined to follow from his natural aptitude or his training.

A crippled man should not be placed merely from compassion in a position which he cannot fill. He should be given work that he can do as well as a whole man, and should receive commensurate pay. Of course, if two men, one a crippled soldier and the other not, make application for the same position, it is hoped that the crippled man would receive preference, assuming he is able properly to do the work.

It is necessary that his work be started *at once*, if not already begun. And it must be pushed. Our boys are not yet returning, crippled, in large number, but they will be coming very soon. We must be ready for treating them properly. The Allies have found it difficult to get hold of soldiers discharged before they were properly reconstructed and reëducated. We can learn from their experiences.

There are some things which can be started in preparation, and I would list them as follows:

(a) A bibliography of the literature on cripples, with suitable card index, by subjects and cross references.

(b) A card index of the different industries, with the different positions in each, and a record of the parts of the anatomy involved in filling

the duties of each position. The strength, skill, training and mental ability needed should also be noted. It may be found that portions of two or more positions might be combined and thus a new position made that could be suitably filled by a cripple.

(c) A card index of the different *positions*, regardless of the industrial relations, which involve the use of the same parts of the anatomy, and with it the strength, skill, training and mental ability. Then a cripple could be informed which industrial activities might be available for him.

(d) A card index of records of individuals already crippled and employed, giving their positions, their handicaps, their artificial aids, their accomplishments.

(e) A collection of motion-pictures of crippled men at work in different lines of endeavor, in home, in factory, or on the farm, showing them happily at work and self-supporting.

(f) Establishment, in a National museum and in State museums, of collections of apparatus for cripples. This would include all kinds of artificial members for the body, and different attachments and appliances to adapt them for use in different trades. The apparatus itself in many cases could be arranged to operate properly by the pressing of an electric button. Many photographs could be incorporated showing the various appliances in use, and even arranged as a set of moving pictures.

(g) Establishment at different places throughout the country of schools of vocational reëducation. These could be grouped in some manner by allied trades, by industries, by the man's available motions. The State Universities and private Universities might coöperate with the Government in giving the training. Some industries might turn over their apprentice schools with equipment to Government control for this purpose of reëducation along the lines of their special industry. But there are many occupations for training in which the Government will have to found new schools.

(h) A card index of the present teachers in the various industries, properly cross-referenced. Many more teachers will be needed than those now employed in teaching industrial lines, and plans must be made to secure some from the industries and train them for teaching.

When our boys begin to fill our hospitals in France, England, and this country, then there will be needed further work of a personal nature dealing with each individual. An outline might comprise these things:

1. The imparting of hope and encouragement to the maimed soldier at as early a period of his physical recovery as possible. This will mean a few cheering words as to the future by doctors and nurses, talks by proper persons, illustrated printed stories, moving pictures of scenes in reëducation and of cripples happily busy at home and at their employment. This mental stimulus will react favorably on the bodily healing.

2. Obtaining the record of each crippled man as given in his questionnaire (if he made one) and supplemented by his hospital record and by his hopes and ambitions as to what he would like to do. These records should be filled out in many cases with the assistance and suggestions of some sympathetic and understanding person.

3. Suitable, temporary "something to do" while he is recuperating from his wound, even while confined to his bed. Much can be done on these lines to prepare for the future vocation. This is accompanied or followed by the necessary kind of therapy.

4. The vocational training of the cripple. Care should be exercised to place him in the line of work which he desires and for which he is physically capable. While it is hoped the proper selection would be made the first time, it should be possible to change him readily to another trade or school if the first choice is wrong.

5. The scientific adaptation of the man to his vocation and the scientific adaptation of the tools and machines to the man. The first will include those appliances added to the man to supply his missing parts, to supplement defective actions and to give other artificial advantages. The second would include changes in and additions to existing equipment to make them workable by the maimed man. In both of these fields there will be needed the inventive faculty of many minds. Much has already been done in other warring countries.

6. The technique of the teaching of cripples will have to be developed. These crippled soldiers will be fresh from the hospitals, not yet completely restored from the nerve-racking experiences of trench, battle, and hospital. The industrial training will be largely the individual laboratory method, and but a few men should be apportioned to each instructor. The instructors will find that they will need more patience and much sympathy for these new pupils. It is hoped that efforts will be made to find the one best way of doing each branch of the work which is taught. Such an investigation should be made with the proper scientific devices, the results of which can be suitably analysed for the elimination of unnecessary or waste motions and of fatigue.

7. The placement of the cripple in the industries through a National employment bureau or its substitute. To do this work properly, the industries must coöperate. The cripples will be listed. Positions available must be sent as they occur to the bureau. A follow-up system must be used to keep track of the cripple.

In the various portions of the work outlined, there is some part in which each one can do his bit. Look over the different items and see if you have not some helpful information which you can furnish. Such information may be sent to the Office of the Surgeon General, Washington, D. C., as this department is looking after the reconstruction features, and some of the reëducation work. Information as to the

latter work might be sent to the Federal Board of Vocational Training, Washington.

The engineers in the industries can surely make a scientific investigation of the different positions, each engineer in his own industry, with reference to the elimination of waste motions and of fatigue, or cause it to be done if he is not prepared to do it himself. It will help on the crippled soldier problem and will react to the benefit of the industry itself.

Social and Religious Organizations as Factors in the Labor Problem

Discussion of the paper of E. E. BACH, presented at the New York meeting, February, 1918, and printed in *Bulletin* No. 134, February, 1918, pp. 321 to 330.

SHELBY M. HARRISON,* New York, N. Y. (written discussion†).—Your secretary requested a brief description of the Russell Sage Foundation, in order that members of the Institute, if they should desire to avail themselves of it, would know what type of service is offered to them through our institution. The foundation was established in 1907 by the gift of Mrs. Russell Sage of \$10,000,000 as a capital fund, the income of which is to be spent for the improvement of social and living conditions in the United States. One of the lines of activity which the foundation has felt would lead toward this end is the development and promotion of community surveys; and because the scope and methods followed in these surveys are very similar to the scope and method of much of the institution's work in general, an idea of its main activities can perhaps be given best by describing one of our surveys.

Incidentally, it may be pointed out that antecedent to the survey stand at least two important facts: first, the recognition that communities are active, not static forces, that they develop, that changes in material and human relationships occur continuously, and that with them come new social and civic problems which must, in many cases, be diagnosed and prescribed for anew; and second, the reality of scientific advances along lines which make possible at least some measure of solution of the problems.

Evidences of these changes are abundant; many of them are found in the rapid growth of cities in the last few decades. Villages in agricultural districts, places where everybody knew everybody else, where the pulpit had been long the chief or only influence molding public opinion, where the air was unclouded by the smoke from factory stacks, where the water supply was not affected by pollution, where sunlight and building

* Director, Department of Surveys and Exhibits, Russell Sage Foundation.

† Received Apr. 5, 1918.

space were plenty, these villages in little more than a generation have leaped to the size of cities, with many of the more complicated problems of sanitation, health, housing, recreation, delinquency, city planning and the like. Moreover, while these changes have been taking place, women in large numbers and multitudes of immigrant peoples have been entering many kinds of industrial life, and the services furnished by the municipality have tended to broaden and increase. These are important changes; but only a few of the many which have introduced maladjustments into community relations calling for new study and constructive effort.

On the other hand, a counter and more hopeful process has been going on, the development of analytical methods for diagnosing these problems and the accumulation of helpful information on corrective and preventive measures. The advances of sociology, of education, government, public finances, have been very marked, but not more so than the big strides which have taken place in the science of public health and sanitation, the fields which touch almost every side of individual and social welfare.

In the midst of this growth of corrective resources, on the one hand, and the changes causing new community problems on the other, the survey has been brought into use. Through it the current problems and the proposed remedies have been brought together. In other words, the survey has meant the application of scientific methods for social betterment.

The most recent general city survey directed by the Russell Sage Foundation was that in Springfield, Ill. It began with a group of Springfield citizens who had been giving some thought to social conditions in their city, had become dissatisfied with them, and had decided that the time had arrived to get out of their maze of conflicting opinions and beliefs and, if possible, onto a basis of certitude in working for community betterment.

There were some citizens, for example, who believed Springfield's public schools the equal of any in the State; others believed they needed to be readjusted to the changed conditions under which the oncoming generation must live and work. Some boasted of the city as the "healthiest place in Illinois;" others believed the number of deaths from preventable causes was too high, and public health appropriations too meager. Some believed that local strikes were due to union agitators who wanted to kick up a fuss; others, that they indicated something wrong with wages, employment opportunities, and general working conditions. There were those who believed law-breakers got what they deserved, but others were of opinion that ill-treatment of offenders provoked crime. And so on, the opinions and beliefs were as conflicting and various as they are in every live, growing American city. Fortunately, the few interested citizens thought it important to give them the test of fact.

A survey committee of twenty-four was organized. The chairman was a State senator, and among the other members were a former lieutenant-governor of Illinois, a State commissioner, the city superintendent of schools, other public officials, business men, labor leaders, clergymen, doctors, women's club leaders, editors, teachers, and social workers.

The survey comprised nine main divisions, which, outlined in mere skeleton, were as follows:

A survey of Springfield's schools, including: the school plant, the children, the teaching force, class-room instruction, course of study, financial administration, medical inspection, intermediate schools, vocational education, educational extension, etc.

A study of methods of finding and caring for mental defectives in the schools and in the community; commitment, treatment and discharge of the insane, and care of alcoholics.

A survey of Springfield recreation, including: the homes, schools, parks, streets, library, museum, semi-public institutions, commercial amusements, athletics, festivals, pageants and public celebrations.

A study of housing tendencies and the legal aspects of housing in Springfield.

A survey of the Springfield charities, including: the children in Springfield institutions, the charitable care of the sick, family disabilities and causes of distress, the social agencies dealing with families, financial considerations, etc.

A survey of work conditions and industrial relations, including: health hazards in industry; hours of labor; child labor; wages and regularity of employment; social effects of work conditions; efforts for industrial betterment, etc.

A survey of the efficiency of the public offices, including assessment and collection of taxes and other revenues; disbursement methods; organization of city administrative functions; budget; city department efficiency; county administrative work; the park board; publicity and reports, etc.

A survey of Springfield's public health, including: infant mortality, contagious diseases of children, the tuberculosis situation, typhoid fever, venereal diseases, city water supply, sewerage and sewage disposal, wells and privies, milk and food supply, and city health department.

A survey of Springfield's correctional system, including: the disposition of cases of arrest, the use of fines, hours to leave town, suspended sentence, jail sentences, indeterminate sentence and parole; probation of adults and children; detention of children; the juvenile court; legislation needs; and the work and policy of the police department.

The facts collected in these nine divisions were in due time analyzed and interpreted, and were followed by the working out by detailed recommendations for improvement. All of the reports were fully summarized

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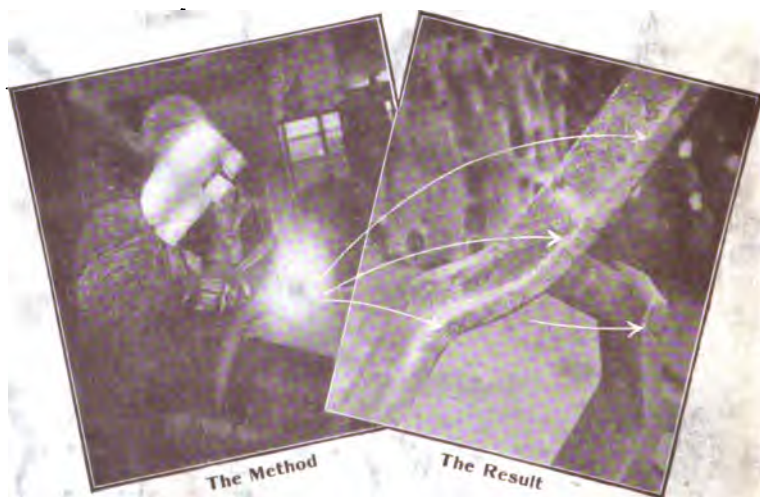
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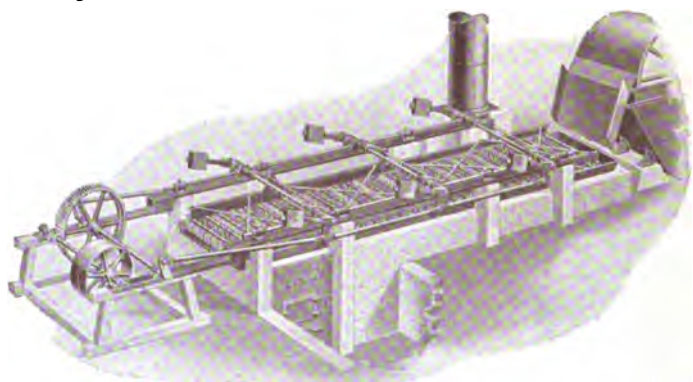
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COLORADO MEETING, SEPT. 2 TO 7, 1918

Preliminary plans of this meeting, together with a most interesting series of papers that have been received or promised, were published in the May *Bulletin*. The plans are being carried out enthusiastically and hospitably by the Colorado members and all indications point to an interesting and valuable meeting.

MEETING OF THE BOARD OF DIRECTORS, APRIL 26, 1918

Eight members of the Board, the Secretary of the Institute, and eleven guests were present.

Vice-president Henry S. Drinker presided.

The President was authorized to appoint delegates to a meeting, on May 16, of the League to Enforce Peace.

The Joint Conference Committee reported that the American Institute of Metals had accepted the invitation to form the Institute of Metals Division of this Institute. The Committee on Publications of the Institute of Metals was added to the Committee on Publications of the A. I. M. E.

Exchange of one volume of *Transactions* of the A. I. M. E. at reduced price to members of the British Institute of Metals was authorized, in return for the reduced price given to our Institute of Metals Division on the annual proceedings of the British Institute.

Authority was given for the presentation of two copies of the *Bulletin* to the General Engineering Depot, U. S. Army; one copy to the Com-

mittee on Metallurgy, National Research Council; and one copy to the United States Tariff Commission; and for the presentation of the *Transactions* to the Cleveland Engineering Society.

The report of the Treasurer was presented in writing and was accepted.

The report of the United Engineering Society's Trustees was presented in writing and was accepted.

Seventy-three members, two associates, and seven junior associates were elected. Five members were reinstated. Twenty-one resignations were accepted. An extension of time was given to various members. The dues of thirty-three members were suspended on account of their being on active duty.

J. W. Richards was nominated as an additional representative of this Institute on the Engineering Foundation Board.

The following resolutions regarding enemy aliens were presented for action at the next meeting of the Board, and it was

RESOLVED: That they be circulated to all members of the Board, with a statement that they would be acted upon at the next meeting of the Board, to the Chairmen of Local Sections and by publication in the *Bulletin* as well as in the Daily Press.

RESOLVED: That all Honorary Members, Members, Associates and Junior Associates who are Enemy Aliens be dropped from membership in the American Institute of Mining Engineers and their names be stricken from the rolls, forever.

RESOLVED: That the Membership Committee be requested to advise this Board of Directors of the names of all above-mentioned persons.

RESOLVED: That publicity of these resolutions be given to members through the Local Sections and by publication in the *Bulletin*, as well as through the daily press.

The sum of \$125 was appropriated to the Colorado Section.

The action of the President and Secretary in inviting to a dinner in New York, on behalf of the Institute, the Chairman of the National Research Council, and other officers of the Council, was approved.

Felicitations were extended to Rossiter W. Raymond, Secretary Emeritus, on the occasion of his seventy-eighth birthday, April 27, 1918.

Upon the recommendation of Vice-president Henry S. Drinker, the Advisory Board of the National Conservation Congress was discharged with the thanks of this Board.

AFFILIATION WITH AMERICAN INSTITUTE OF METALS

The Board of Directors, at its meeting on March 22, 1918, extended an invitation to the American Institute of Metals to become the Institute of Metals Division of the American Institute of Mining Engineers in accordance with the terms of By-Law VII. This invitation was presented to the membership of the American Institute of Metals for letter ballot, and at the meeting of the Board of Directors of the American Institute of Mining Engineers on April 26, 1918, it was reported that the replies had been in favor of accepting the invitation. The American Institute of Metals therefore becomes a division of this Institute and the members thereof are entitled to all privileges of regular

U.S. Geol. Survey

members of the Institute. In this connection, attention is called to the following notice of a meeting of the Institute of Metals Division and the Iron and Steel members of the Institute, at Milwaukee in October.

MILWAUKEE MEETING OF THE IRON AND STEEL MEMBERS OF THE INSTITUTE

In accordance with authority given by the Board of Directors, the Iron and Steel Committee has arranged for a meeting of the Iron and Steel members of the Institute at Milwaukee, Wisconsin, Oct. 8, 9 and 10, 1918. Papers on iron and steel will be presented and discussed and it is believed that joint sessions will be held with the Institute of Metals Division of the Institute and also with the American Foundrymen's Association which will meet at the same time and place.

Milwaukee was chosen as the place of meeting and the dates specified were chosen because they had been selected for the meeting of the Foundrymen's Association and the authorities of the Association accept this cordial invitation in favor of the joint meeting. It is possible that one or more joint sessions of the various societies may be held where papers of much interest will be read.

Further announcement will be made in the *Bulletin*.

The closing date for acceptance of papers for this meeting is July 1, 1918. The Iron and Steel Committee has promised a number of important papers for this occasion.

WAR ACTIVITIES

THE FIFTH NATIONAL FOREIGN TRADE CONVENTION

The fifth convention of the National Foreign Trade Council was held in Cincinnati, Apr. 18, 19 and 20. More than one thousand accepted delegates were registered, the American Institute of Mining Engineers being represented by W. L. Saunders and W. N. Thayer.

The convention was called to order Thursday morning, Apr. 18, in the convention hall of the Hotel Gibson, by the Chairman, Mr. James A. Farrel, president of the U. S. Steel Corporation, and was in continuous session for two days, several group sessions being held simultaneously. The convention adjourned Saturday morning after receiving the report of the central committee.

The dominant themes of the convention were: First, "Win the War" and second, "Establish Foreign Trade on a Firmer Basis." The discussions included textiles, lumber, chemicals, automobiles, finance, and agriculture, and also those things in which mining engineers are particularly interested, metals, oil, and coal.

The report of the central committee, which was adopted, recommended the stimulation of production of all materials required for war purposes; the subordination of all trade that will not impose new and heavy penalties on our adversaries; the maintenance of such foreign trade as will support national credit and supply materials required for military and naval purposes; the continued interchange so far as possible of merchandise and products between the United States and Latin-America, Asia and Oceania; the immediate increase of tonnage in the north Atlantic; the cheerful and whole-hearted coöperation of importers

and exporters with the War Trade Board, to the end that we may strengthen our hold upon the trade heretofore monopolized by the Central Powers; the utilization of south Atlantic and gulf ports in order to relieve the congestion at the eastern terminals; the improvement and extension of our inland waterways, under a broad and economical national policy, to supplement our system of railroad transportation; the training of youth in schools, colleges and universities in the principles and economics of foreign trade; the adoption by Congress of a flexible or bargaining tariff; and the taking of an inventory of national assets in anticipation of the reconstruction era.

The convention commended the enactment of the Webb-Pomerene law authorizing coöperation in foreign trade, and condemned the failure of Congress to grant adequate appropriations for foreign trade promotion through the consular service and the Department of Commerce.

The delegates attended a banquet on Friday evening at the Hotel Gibson. The toast-master was L. A. Ault of the Ault-Wiborg Co., Cincinnati, and the speakers were James A. Farrel and E. N. Hurley, Chairman of the U. S. Shipping Board.

THE GOVERNMENT NEEDS ENGINEERS

In the Bureau of Mines

Important chemical and other technical engineering work necessary for the prosecution of this war is being carried on by the Bureau of Mines Experiment Station, at Washington, D. C. The services of trained men of the following classifications are urgently needed:

Bacteriologists	Instrument makers
Biologists	Laboratory Assistants
Chemists, Inorganic	Laborers
Chemists, Organic	Machinists
Chemists, Physical	Physiologists
Chemists, Electro-	Plumbers
Chemical Engineers	Steamfitters
Draftsmen	Stenographers
Electrical Engineers	Skilled labor of various kinds

If your training fits you for any of these occupations, send to the Bureau of Mines,

American University Experiment Station,
Washington, D. C.

for blank forms. When properly executed and returned by you, these forms will be placed on file, and when a vacancy occurs you will be considered for it and will be notified if your services are desired.

If you are a registrant in the draft, and have not yet been ordered to camp, it may be possible to have you immediately inducted into the service for work here.

If you are *not* in the draft, but feel that you wish to serve your country in the present crisis, you can enlist, or serve as a civilian.

Serve your country where you can serve it best.

VAN H. MANNING, *Director*.

For Service on Submarines

The Secretary of the Navy has requested nominations from the National Research Council, of specially qualified professional engineers who desire submarine duty. The submarine force of the Navy is being augmented by numerous vessels and it has become essential to select reserve officers for training in this service. The usefulness of these men depends largely upon possession of certain special qualifications.

These qualifications include:

- (a) Citizenship in the United States.
- (b) A desire to serve in submarines.
- (c) A degree of Mechanical Engineer, Electrical Engineer, or Mining Engineer, conferred by a college of recognized technical standing.
- (d) At least two-and-one-half years' practical engineering experience subsequent to graduation (exclusive of time spent as sales agent).
- (e) Not over thirty-five years of age.
- (f) Physically strong and sound in health.

From nominations submitted in accordance with this request, candidates will be selected and commissioned as Ensign in the U. S. Naval Reserve Force and sent to the U. S. Naval Academy for intensive training course.

Those who finish this course successfully will in turn be sent to a submarine school for a special technical course preliminary to detail as submarine officers of the Navy.

The utmost care will be exercised in the nomination of candidates as regards professional ability, physical condition, temperament and bearing.

The Provost Marshal General of the U. S. Army has stated that anyone subject to the Selective Draft Law may be released therefrom to accept a commission in United States Naval Reserve Force.

Anyone who is now in the Army, either volunteer or drafted, may make application but must obtain his discharge before he can be appointed. This includes anyone who has been directed to appear before an Exemption Board. Those now in the Naval Reserve are eligible.

Letters from at least three responsible personal acquaintances should accompany each application.

Applications may be addressed to the American Engineering Service, Room 903, 29 West 39th Street, New York City.

For General Service in the Navy

The Bureau of Navigation, Navy Department, is desirous of securing trained engineers for general service in the Navy in steam engineering, electrical engineering and radio duties.

Applicants for this service will, if accepted, be enrolled as Ensigns in the Naval Reserve Force and will be sent to the Reserve Officers' school at Annapolis for a special course of about four months, after which those who finish this course successfully will be placed in further training ashore or afloat, and then become available for regular sea or shore duty, as the exigencies of the service may demand.

Applicants for this general service should have the following qualifications:

- (1) A degree in Mechanical, Electrical or Mining Engineering, conferred by a college of recognized standing.
- (2) At least two and one-half years' practical engineering experience subsequent to graduation (exclusive of time spent as sales agent).
- (3) Not over thirty-five years of age.
- (4) Physically strong and sound in health.

The American Institute of Electrical Engineers, American Institute of Mining Engineers, American Society of Mechanical Engineers, Naval Consulting Board and National Research Council, have each been requested to submit a list of fifty names equally proportioned among personnel trained in

- (1) steam engineering duties,
- (2) electrical engineering duties,
- (3) radio duties;

but the exact engineering duties to be performed in general service by each applicant will be decided after completion of the training under Naval supervision.

It is probable that a class will be formed at the Naval Academy about the middle of June.

Each applicant should without delay forward a résumé of his education and engineering experience, together with a small photograph, if practicable, and such letters of recommendation as it may be possible to submit, to the Engineering Council (which is acting for the five organizations named), 29 West 39th Street, New York.

In the Auxiliary Service of the Navy

The United States Navy Department has perfected plans for the enrollment and training of considerable numbers of engineering officers. A school for this training, known as the United States Navy Steam Engineering School, has been established at the Stevens Institute of Technology, Hoboken, N. J., under the guidance of Dean F. L. Pryor as Civilian Director.

The course consists of five months' training divided as follows:

One month of military training at the Naval Training Camp, Pelham Bay Park, New York.

One month at the U. S. Navy Steam Engineering School.

Two months' practical training on board ships and in repair shops in the vicinity of New York.

One month finishing course at the U. S. Navy Steam Engineering School.

The school is open to men between 21 and 30, who are physically qualified, of thorough ability and officer-like character, and who have completed the engineering course at any recognized technical school. This school presents desirable opportunities to the young technical man, both in affording him a proper outlet for his trained faculties during the war, and in rounding out his college work with a practical course and school experience which will be of value to any engineer.

The service that a graduate from the school will perform will be that of an engineer-officer in the auxiliary service of the Navy. A graduate

of the school will be commissioned an Ensign in the U. S. Naval Reserve Force.

Information has been sent to all registered technical schools and should be on file at the President's office. For any additional details, application can be made to the Civilian Director, U. S. Navy Engineering School, Stevens Institute, Hoboken, N. J.

Any men, graduates or undergraduates, who are registered in the draft, can enroll with the proper enrolling officer by securing from the draft board a letter of release, which in all probability can be obtained for this purpose, provided the men are not included in the current draft quota.

Special provision has been made for the continuance of the school with proper material, by a Navy regulation which permits undergraduates of the Freshman, Sophomore and Junior classes in recognized engineering schools to enroll in the Navy with a rating Seaman 2d Class and continue their courses at the institutions where they have matriculated. Such men will be called into active service after their graduation and can at that time, if they are qualified to pass an officer's physical examination, enroll for the course at the U. S. Navy Steam Engineering School.

In Forest Production

See Positions Vacant, No. 313.

NEWS FROM MEMBERS AT THE FRONT

Albert Sauveur writes, on Apr. 16, 1918, while the German offensive was at its height, as follows:

"In spite of the German guns and air raids we are all in good health and spirits and shall leave Paris only as a last extremity. Our unlimited confidence in Foch, however, makes us believe that it will not be necessary. I trust that everything is well with you at the Institute."

Harold Whittingham entered the active service with the heavy artillery in England at the beginning of the war and has been fighting in France since February, 1915. He now holds the rank of Major. On Dec. 17, 1917, after being wounded, he was taken prisoner by the Germans, and, so far as is known, is still in a prison camp in Germany.

Charles W. Wright, who is a Captain in charge of the work of the American Red Cross in Sardinia, Italy, writes that the service there is giving aid to about 80,000 soldiers' families and is upholding the good repute of America in that place.

W. S. Holloway in 1914 joined the Sportsman's Battalion of the Royal Fusiliers as a private, but is now a Lieutenant in the Royal Engineers, Mining Corps. He received the Military Cross while mining at the Front in France.

A. L. Queneau writes the following interesting account of his experience of the war. Several letters from Mr. Queneau have been published

in the technical press, but his many friends in the membership of the Institute will be interested in the following story:

"The French mobilization, which took place on Aug. 1, 1914, found me at Liege, where I was in charge of an electric zinc smelting plant at the Valentin-Cocq Works of the Vieille Montagne.

"Leaving Mrs. Queneau and the children, I departed immediately for Paris, where I arrived on the 3d August to rejoin as private my regiment of mobilization—the 4ieme. Régiment d'Artillerie Lourde. Our regiment took a very active part in the erection of the new Paris defences to meet the on-coming rush of the army of Von Kluck.

"Early in November, 1914, volunteers, speaking English, were asked to proceed to the British front as interpreters to the British army. I thus found myself attached to the Royal Engineers of the 27th British Division, with which regiment I remained from December, 1914, to October, 1915, in the Ypres salient. During this time I was promoted successively to Corporal, Sergeant, and Officer Interpreter. I also had the good fortune to receive the British decoration for Distinguished Service in the field, and the French Croix de Guerre.

"At the instance of the British Ministry of Munitions, I was recalled from the front to act in an advisory capacity in regard to lead and zinc smelting. This work I have been carrying on up to date, but I expect to leave shortly for the front in view of the present military crisis.

"I will send you my address as soon as the change is made, but for the present may add that I trust to have my appointment as Liaison Officer with the American army in France.

"With kindest regards to yourself and our mutual friends."

TOWNSHIPS NAMED FOR MINING ENGINEERS

The following communication has just reached the Institute, from the office of the Provincial Geologist, Department of Lands, Forests and Mines, Ontario, Canada:

During the autumn of 1917 gold was discovered in unsurveyed territory south of Lake Abitibi in northeastern Ontario. This area lies about 70 miles almost directly east of the well known Porcupine area.

During the coming summer, the Ontario Bureau of Mines is to make a geological survey of this new gold area. Following the custom of Ontario, this area is being divided into townships, 6 miles square. These townships have recently been given the following names in honor of men well known in the mining and geological world. In alphabetical order the names are as follows:

Frecheville—Prof. Wm. Frecheville, Professor of Mining in the Royal School of Mines, London; Past President of the Institution of Mining and Metallurgy.

Garrison—Mr. F. Lynwood Garrison, Mining Engineer, Philadelphia, Pa.

Harker—Dr. Alfred Harker, F. R. S., immediate Past President of the Geological Society of London.

Holloway—The late George T. Holloway, Chairman of the Royal Ontario Nickel Commission, 1915-17.

Lamplugh—Mr. G. W. Lamplugh, F. R. S., President of the Geological Society of London.

Marriott—Mr. Hugh F. Marriott, President of the Institution of Mining and Metallurgy, London.

Rand—Mr. Chas. F. Rand, Past President of the American Institute of Mining Engineers, New York.

Stoughton—Bradley Stoughton, Secretary of the American Institute of Mining Engineers, New York.

WOMAN'S AUXILIARY**Report of the Americanization Society, New York Section**

During the past two months the Americanization Committee has held social meetings of various kinds for foreign-born women, as a preliminary to future effort along the lines of Americanization work. At the same time, a thorough investigation was made as to the work being done in New York by organizations devoted to this interest. The committee will be very glad to help any other committees being formed in mining centers, with advice and information that has been gathered together as to classes and meetings of all kinds best suited to the needs of a foreign-born population. The work has been so extensively taken up in New York that for the present it would seem to be, for this committee, the most profitable and interesting work to continue the social meetings and to undertake the care of one or more immigrant families, to be friend and adviser in joy and sorrow, work and play, and in this way do some fundamental Americanization work.

Respectfully submitted,

LAURA G. BURGER, *Chairman.*

Report of the Emergency Committee, New York Section

Since the last report presented to the Council in April, 1918, the order for the knitted articles for immediate delivery, as mentioned in that report, has been filled, and work is progressing on the balance of the order.

My committee has to thank Mrs. Thomas Stearns, Chairman of the Colorado Section, for the comfort kits received, and also a number of others for their generous donations of knitted articles.

A concert was held at the Hotel des Artistes and proved a great success, thanks to the energies of Mrs. Hardinge and Mrs. Ihlseng, and the Emergency Fund has benefited to the extent of \$141.61.

Monday and Tuesday of each week have been assigned to the Emergency Committee for the workroom in the Engineering Building, and help in this direction is urgently needed.

On behalf of my committee, I wish to thank Mr. Gresham for his valuable assistance.

Respectfully submitted,

LAURA H. SPICER, *Chairman.*

Report of the Foreign War Relief Committee, New York Section

Since its formation, two months ago, this committee has raised \$935 for the purpose of providing a flock of sheep for the Aisne District. Three hundred dollars of this sum has been sent to the American Committee for Devastated France, and the balance is being held until such time as it shall again seem advisable to resume work in the devastated districts. Under the auspices of the committee, a course of four lectures on the war has been given, and the proceeds will be devoted to our work.

When General Pershing was asked last spring by the Red Cross "What could we do for you?" he replied "For God's sake do something for the families of French soldiers!" and this behest is being met by the establishment of dispensaries by the American Fund for French Wounded. These dispensaries, maintained at an approximate cost of

\$3000 a year, are centers to which the women and children can go for aid. Each one is in charge of a volunteer worker, and one or more assistants, and has a motor truck and driver, all supplied by the American Fund. The Red Cross provides a doctor and a nurse. The \$3000 provides the rooms and all medicines and surgical materials and any urgent needs. The dispensary stands in the name of the donor. The work is of incalculable benefit to people who have suffered all the hardships and, in the North, the horrors of war for nearly four years, and who, through the multitude of demands made upon them, are unable to meet the needs themselves. We must give, and give lavishly if the children of France are to be saved. This committee feels that in making this appeal it is asking assistance for a people who have given us so splendid an example of sublime heroism and sacrifice that it should be esteemed a privilege to help them by our renouncements.

Respectfully submitted,

SOPHIE CARY KNOX, *Chairman.*

The General Council

At the meeting of the General Council, held on May 6, it was decided that, provided the chairman, treasurer and secretary of any of the Welfare Committees be members or associate members of the W. A. A. I. M. E., other members of the committees need not necessarily belong to engineering societies.

Very interesting letters have been received from Major Dwight, thanking Mrs. Prosser, former Chairman of the Emergency Committee, for the check of \$141 to be used for his regiment and for the Christmas boxes, which arrived in March, and were even more welcome, he writes, to the fifteen hundred men than if they had arrived at Christmas time.

LOCAL SECTION NEWS

ST. LOUIS SECTION

EUGENE MCAULIFFE, *Chairman*, J. N. HOUSER, *Vice-chairman*,
 VICTOR RAKOWSKY, *Vice-chairman*, H. G. WASHBURN, *Vice-chairman*,
 W. E. MCCOURT, *Sec'y-Treas.*, Washington University, St. Louis, Mo.
 H. A. BUEHLER, G. H. COX,
 E. A. HOLBROOK, W. E. NEWNAM.

The eighth meeting of the St. Louis Section was held at the Mercantile Club on Apr. 15, 1918. The meeting was preceded by a dinner, at which 51 members and guests were present, and at which T. T. Brewster presided. Bradley Stoughton, Secretary of the Institute, and Major J. R. Fordyce were the guests of the Section.

A number of the Joplin members were obliged to leave before the close of the dinner, in order to make train connections. The Vice-chairman, therefore, called on Victor Rakowsky, who brought a message of greeting from the Southwest district.

At the close of the dinner, the Vice-chairman, T. T. Brewster, introduced Bradley Stoughton, who talked on various subjects of interest to members of the Institute, especially the affiliation of local sections with those of other national engineering societies.

The minutes of previous meetings were read and approved and the Treasurer presented a financial report covering the previous year.

This was accepted and approved. The Secretary reported that during the year 1917, 171 in the St. Louis territory were proposed for membership in the Institute and, during the same period, 136 were elected to membership. He also reported that 121 had withdrawn from membership in the Section to join the recently organized Tulsa Section. Even with this, the present membership of the St. Louis Section is 292, a gain of 24 over last year. He announced that though records are incomplete and possibly inaccurate, it appears that nearly 40 members in the St. Louis district are in National Service.

A report submitted by a committee appointed to investigate the question of affiliation with the Associated Engineering Societies of St. Louis was presented and referred to the Executive Committee for action.

H. A. Buehler, Chairman of the General Committee in charge of the October meeting of the Institute, made a brief report, and the Treasurer submitted a final financial statement, which was accepted and approved. The Section unanimously voted to use the balance of the fund to purchase Liberty Bonds, and the Treasurer was authorized to make the purchase.

The Nominating Committee then placed in nomination the men whose names appear at the head of this announcement, who were duly elected to serve during the year 1918.

Philip N. Moore presented a tribute to J. W. Malcolmson, who died during the past year.

The Vice-chairman presented the Chairman, H. A. Buehler, who presided during the remainder of the program. Addresses were made by F. W. DeWolf, Arthur Thacher, and Congressman W. L. Hensley. Major Fordyce, a member of our Section, described the building of Camp Pike, Arkansas, of which work he was in charge. His talk was illustrated with splendidly vivid motion pictures.

W. E. McCourt, *Secretary*.

COLUMBIA SECTION

S. S. FOWLER, *Chairman*,

J. C. HAAS, *Vice-chairman*,

LYNDON K. ARMSTRONG, *Sec'y-Treas.*, 720 Peyton Bldg., Spokane, Wash.

W. H. LINNEY,

J. F. MCCARTHY.

Columbia Section had called a meeting for the evening of April 8, and, on account of the arrival in Spokane of Messrs. C. W. Goodale, Vice-president of the Institute, and Bradley Stoughton, Secretary, the Section also arranged a luncheon for the same day.

The evening meeting was preceded by a dinner at the Davenport Hotel. Sixty members and guests were present, about one-fourth of the number being ladies. Vice-chairman J. C. Haas presided.

Mr. Goodale, being called upon, reported on some of the present and proposed activities of the Institute and its members in relation to the war and otherwise. He referred first to the National Americanization Committee and the work which it is doing and planning to safeguard the nation against the enemy within. Human Engineering was his next subject. He cited what is being done to aid the foreigner in education and culture to the end that he may make a good American citizen; also to destroy the class differences between the residents of the country. In this connection, he referred briefly to the important position of the women of America and to the Woman's Auxiliary of this Institute, and the aid they can lend in this important work.

Touching upon the activities of the Anaconda Copper Company, he stated that it is undertaking the metallurgy of manganese and will continue to expand its useful activities as rapidly as demands require and circumstances permit.

Following Mr. Goodale, the chairman introduced Mr. Stoughton, who addressed the members and their guests upon the following subjects:

War Work

Of the Woman's Auxillary

Of the A. I. M. E.

Naval Consulting Board

War Committee of Technical Societies

War Minerals Committee

Metallurgical Research Committee

Eleventh and 27th Engineers

He was especially warm in his praise of Van H. Manning, Director of the U. S. Bureau of Mines, citing many of the things which the Bureau is doing under direction of Mr. Manning, who anticipates demands and meets them with precision and dispatch.

He asked the executive committee of the Columbia Section to determine and advise as to what time in the year would be best for the officers of the Institute to make their annual tour.

He delivered a message from President S. J. Jennings, to the effect that he regretted his inability to be present on this occasion but promising to visit the section later on.

Some reference was made to a possible change in the Year Book whereby the profession or business connection of members may be indicated.

At some length, Mr. Stoughton explained a suggestion to change the name of the American Institute of Mining Engineers to American Institute of Mining and Metallurgy, and requested the members to express opinions upon the subject. After several members had endorsed the suggestion of change, upon motion of Frank A. Ross, seconded by J. C. Ralston, the secretary was instructed to record the unanimous endorsement of the proposed change of name by the members present.

Mr. Fred Adams, representing the U. S. Food Administration, then spoke briefly in the interest of food conservation.

Mr. J. C. Ralston spoke of some of the war activities, paid a high tribute to the work of the Woman's Auxillary of Columbia Section, and suggested the possibility of developing a ferro-alloy industry here.

Mrs. Frederick Keffer then read a report of the work of the Woman's Auxillary of the Columbia Section. This auxiliary has conducted an educational campaign to awaken householders to the need for saving certain foods and using substitutes. It has urged the housewife to can and dry fruits and vegetables, and has met with excellent response. The Auxillary worked with the Red Cross during the winter, and is now planning for a busy summer of food conservation.

Mrs. Keffer entered a plea for a larger membership. There are 20 members enrolled, but there could be nearly double that number if the ladies of the households of members in this section would join.

Mr. S. A. Easton was supported by J. F. McCarthy in extending a special invitation to the officers of the Institute to include the Coeur d'Alene district in their next itinerary, regretting the fact that time would not permit on the present trip.

Mr. W. H. Linney reported having recently visited Nevada, where he found Oscar Gillice busily engaged in mining and shipping manganese oxide at a profit.

Mr. H. G. Miller, member of the American Society of Mechanical Engineers, reported that the secretary of that society will soon be in Spokane and inquired if he could not meet some of the engineers. Mr. Miller was assured that such an event would be heartily approved by the members of Columbia Section.

Upon suggestion, the chairman appointed a committee to draft a memorial upon the death of Mr. A. Stanley Hill, a Coeur d'Alene member at the time of his death. This committee consisted of Messrs S. A. Easton, J. F. McCarthy and L. K. Armstrong, the secretary being ordered to transmit a copy of the memorial to the widow, one to headquarters in New York City and to place one in the permanent records of Columbia Section.

The Meeting thereupon adjourned.

L. K. ARMSTRONG, *Secretary*.

MEMBERS OF THE INSTITUTE IN MILITARY SERVICE

(The following list contains the names of those members of the Institute of whose connection with military service we have only recently become acquainted; it also includes the names of a few who have recently been promoted or transferred. A complete list was published in the Year Book, issued as a supplement of the *Bulletin* for March, 1918.)

ARNOLD, RALPH, Member of Board of Tax Reviewers in connection with the administration of the War Revenue Act.

BACON, RAYMOND F., Lieutenant-Colonel, Chemical Service Section, N. A., A. E. F.

BALLENBERG, A. G., 1st Lieutenant, Ordnance Dept., U. S. A.

BARCUS, WALTER J. E., Captain, Gun Division, Ordnance Officers' Reserve Corps.

BECKWITH, H. T., Captain, Engineer Reserve Corps, Headquarters Co., 312th Engineers.

BEESON, JOSEPH J., Company E, 318th Engineers.

BENHAM, W. M., Min. Engr., Headquarters Co., 115th Engineers.

BLACK, THOMAS B., 1st Lieutenant, 338th Field Artillery.

BLAIR, GEORGE S., 1st Lieutenant, 320th Field Artillery.

BUCKINGHAM, ALBERT, U. S. S. *Coronet*.

BURRAGE, ROBERT H., Lieutenant, 27th Engineers.

CANTON, WILLIAM R.

CARLTON, D. P., Corporal, Co. A, 27th Engineers.

CARSTENS, C. E., Sergeant, Chemical Service Section.

CHASE, LYSLE, Corporal, Canadian Engineers Armories, Toronto, Ont., Canada.

CHIDESTER, W. B., 1st Lieutenant, 24th Machine Gun Batt.

CLAGHORN, D. MONTGOMERY, 1st Lieutenant, 45th Engineers.

CLAGHORN, JAMES L., Lieutenant, Aviation Section, Signal Corps, U. S. Army, Ellington Field, Houston, Tex.

- COHEN, MAXWELL B., Aviation Section, Signal Corps, Detention Camp, Section B., Waco, Tex.
- DOENNECKE, H. W., U. S. Gunpowder Reservation, Detachment B.
- DOUGHTY, JOHN H., Captain, Engineer Reserve Corps, Tank Service, A. E. F.
- DWYER, C. EUSTACE, 1st Lieutenant, Ordnance Reserve Corps, Gunpowder Reservation.
- EAGLES, R. H., C. S. S., U. S. N. A.
- EICHRODT, CHARLES W., Reserve Officers' Training Camp, Camp Shelby, Hattiesburg, Miss.
- EUSTIS, F. A., Special Agent, U. S. Shipping Board.
- FOX, ALFRED, JR., Captain, Royal Artillery, British Army.
- GAMM, H. F. E., Mining and Mechanical Engineer, Air Nitrates Corp., agent for Ordnance Dept.
- GOLICK, TONY F., Inspector of Ammunition, U. S. Government.
- GRUNSKY, CARL E., JR., Captain, 115th Engineers.
- HEINE, BERNHARDT E., Aviation Corps, U. S. Army, Call Field, Wichita Falls, Tex.
- HENDERSON, GEORGE M., 1st Lieutenant, Co. A, 306th Engineers.
- HOLLOWAY, W. S., Lieutenant, Mining Corps, Royal Engineers.
- IMHOFF, WALLACE G., U. S. School Military Aeronautics, Mass. Institute of Technology, Cambridge, Mass.
- IONIDES, S. A., British Acetones, Toronto Ltd.
- JEFFRIES, ZAY, Light Alloy Sub-Committee, National Advisory Committee for Aeronautics.
- JOHNSON, J. T., Corporal Co. C, 27th Engineers.
- JOHNSTON, FRANCIS B., Camp Lee, Petersburg, Va.
- KINSLEY, ARTHUR C., Captain, Co. D, 115th Engineers.
- LIDDELL, DONALD M., Captain, Aircraft Board, New York, N. Y.
- M'ALLEN, JOHN L., Lieutenant, 602d Engineers.
- MCBRIDE, R. N., 2d Lieutenant, Engineer Corps.
- MCERODAN, BYRON A., Lieutenant, Canadian Engineers.
- McMEEKIN, CHARLES W., Major, Engineer Reserve Corps, Army War College, Washington, D. C.
- MEAD, HARRY L., Major, Quartermaster's Corps, N. A.
- MEIN, WILLIAM WALLACE, Licensing Agent for manufacturers of acids, fertilizers, sulphur, etc., Dept. of Agriculture.
- MELLER, HARRY B., Captain, Personnel Dept., Equipment Division, Aviation Section, Signal Reserve Corps, Washington, D. C.
- MILLER, ROY H., Co. D, 316th Supply Train, Camp Lewis, Wash.
- MUNOZ, PAUL J., Captain, Ordnance Reserve Corps, Construction Quartermaster, Augusta Arsenal Depot, Augusta, Fla.
- NORTON, PAUL T., JR., Signal Reserve Corps, Aviation Section.
- PETERSON, AXEL M., Co. A, 27th Engineers.
- PICKARD, T. R., 7th Co., Engineer Officers' Reserve Training Camp, Camp Lee.
- POND, WALTER F., 1st Lieutenant, Co. D, 30th Engineers.
- RABLING, HAROLD, Australian Field Engineers.
- RALPH, THOMAS G., Student Officer, U. S. Naval Aviation Detachment, Mass. Institute of Technology, Cambridge, Mass.
- RAY, JAMES C., Captain, 603d Pioneer Regiment.
- RIDDELL, G. C., Metallurgical Expert, U. S. Tariff Commission.
- READ, T. T., Control Bureau, Ordnance Department.

ROBERTS, DUDLEY E., Engineer of Tests, Inspection Division, Ordnance Department.

ROBERTS, MORGAN E., 60th Engineers.

RODEGERDTS, C. A., C. Q. M., U. S. Navy.

RUSS, LEON F., 2d Lieutenant, Signal Reserve Corps, Aviation Section.

SACKET, CHARLES T., Co. H, 1st Replacement Regiment.

SCHLOSS, JOHN M., 3d Training Co., 4th Camp, Fort Monroe, Va.

SELBIE, CHARLES C., 1st Lieutenant, 55th Engineers.

SMALL, H. L., Captain, Co. K, 3d Provisional Regiment, Ordnance Training Camp, Hancock, Ga.

SMITH, A. H., Cadet No. 153901, R. A. F.

SMITH, CHARLES A., Officers' Training Camp.

SNELL, LESTER, Lieutenant, Coast Artillery, State of Washington.

STANFORD, H. R., Commander, Civil Engineer, U. S. N.

TARR, RUSSELL S., Co. A, 27th Engineers, A. E. F.

TAYLOR, DAVID, Captain, Ordnance Reserve Corps.

TINSLEY, ROBERT B., Captain, Engineers' Training Camp.

TURNER, WILLIAM J., Captain, Signal Reserve Corps, Aviation Section, Dorr Field, Arcadia, Fla.

TYLER, PAUL M., Special Expert, U. S. Tariff Commission.

VAN SICLEN, MATTHEW, 1st Lieutenant, Aviation Section, S. R. C.

WALLIS, H. BOYD, Lieutenant, Field Censors, France, B. E. F.

WATKINS, JOSEPH C., Major, 66th Engineers.

WHITEHEAD, WALTER L., 3d Officers' Training Camp.

WOODWARD, W. M. H., 1st Lieutenant, 471st Engineer Depot.

ZIMMERMAN, S. H., Co. C, 107th Engineers, A. E. F.

PERSONAL

The following is an incomplete list of members and guests who called at Institute headquarters during the period Apr. 10, 1918 to May 10, 1918.

Robert H. Chapman, Washington, D. C.	Francis Nicholson, Charlotte Court House, Va.
G. A. Collins, Seattle, Wash.	F. S. Platt, Australian Imperial Force.
W. N. Cummings, Orange, Cal.	H. Rabling, Melbourne, Australia.
W. A. Deane, Summitville, N. Y.	James C. Ray, Palo Alto, Cal.
H. W. Edmondson, Camp Lee, Va.	Jasper T. Robertson, Chicago, Ill.
H. F. E. Gamm, Rutherford, N. J.	John A. Root, Kings Mills, Ohio.
A. L. Gholz, Minneapolis, Minn.	Robert H. Seip, Franklin, N. J.
H. H. Hodgkinson, Dover, N. J.	Trevor B. Simon, Morristown, N. J.
Norman L. Jenks, Marmato, Colombia, South America.	H. N. Stronck, Chicago, Ill.
Paul S. King, Wilmington, Del.	Benjamin F. Tillson, Franklin, N. J.
Ray G. Knickerbocker, Rolla, Mo.	J. R. Underwood, Granby, Mo.
Carl A. Lewis, Habana.	Thor Warner, Phoenix, Ariz.
Robert S. Lewis, Salt Lake City, Utah.	G. B. Waterhouse, Buffalo, N. Y.
Edmund Newton, Minneapolis, Minn.	W. M. Weigel, Renfrew, Ont., Canada.
Alexander Nicholas, Australian Imperial Force.	Chas. F. Willis, Tucson, Ariz.

Ralph Arnold is devoting a part of his time to work as a member of the Board of Tax Reviewers in connection with the administration of the War Revenue Act.

R. C. Bergen, assistant editor of *Metallurgical and Chemical Engineering*, has resigned his position to go into manufacturing work. He has been with the journal since its change to a semi-monthly in 1915, and was formerly with the Roessler & Hasslacher Chemical Co.

H. A. Brassert has accepted a position as consulting engineer with Freyn & Co., Chicago, Ill.

William M. Brewer has been appointed resident engineer, Western Mineral Survey District, Nanaimo, B. C., Canada.

Arthur W. Burgren is now superintendent of the Bonney mine, Lordsburg, New Mexico.

Theodore H. M. Crampton has accepted a position as engineer of the Swansea Lease, Inc., Swansea, Ariz.

E. R. Crutcher is with the Mt. Read & Rosebery Mining & Smelting Co., Ltd., Queensland, Tasmania, Australia, as metallurgical engineer.

Fletcher G. Downs is with the Ely Copperfield Associates, West Fairlee, Vt.

Richard H. Ernest has been elected vice-president and general manager of the Manhattan Oil Co., Tulsa, Okla.

H. F. E. Gamm has received an appointment as mining and mechanical engineer of the Air Nitrates Corporation, which is the agent for the Ordnance Department at 360 Madison Avenue, New York, N. Y.

Justice Grugan wishes to inform his clients and friends that he has discontinued his mining engineering office at 30 Church Street, to assume the duties of chief engineer for the Suffern Co., 135 Broadway.

G. W. Hain has accepted a position as superintendent of the Detroit Rock Salt Co., Navarre, Mich.

William J. Hayes is now mining engineer, Compania Minera Chocó-Pacífico, Andagoya, Colombia, South America.

Fred N. Hays is with the Jones & Laughlin Steel Co., Pittsburgh, Pa.

John M. Hyslop has resigned his position with the Hubbard Steel Foundry Co., and is now with the Mesta Machinery Co., Homestead, Pa.

Irving H. Johnston has resigned his position as chief chemist of the Continental Motor Corp., Detroit, Mich., and is now with the Pittsburgh Testing Laboratory, 1550 Monadnock Bldg., Chicago, Ill.

R. D. Jordan has accepted a position with the Taylor-Wharton Iron & Steel Co., High Bridge, N. J.

Y. C. Kuang is now mining engineer and geologist with the Tung Hui Industrial Development Co., Ltd., No. 8, Jung Hsien St., Peking, China.

Victor E. Lieb is in the U. S. Reclamation Service, El Paso, Tex.

Stuart B. Marshall, formerly manager of American Manganese Mfg. at Dunbar, Pa., and until recently general superintendent of the Aluminum Company of America's Tallassee Power Co., Badin, N. C., is now located at Roanoke, Virginia, as consulting engineer, chemist and metallurgist for coal and ore lands, blast furnaces, coke ovens, foundries, minerals, manganese deposits, ferro-manganese and spiegel operations, and so forth.

Edwin M. Mohrman has been appointed district manager, Truscon Steel Co., 621-622 Hippodrome Bldg., Cleveland, Ohio.

Harold A. Morrison has accepted the position of superintendent of the Tybo Mine, Louisiana Cons. Mining Co., Tonopah, Nev.

LeRoy A. Palmer has resigned as mineral examiner, U. S. General Land Office, to take a position as field engineer with the Suffern Co.

Horace G. Pomeroy has accepted a position with the Mammoth Development Co., Shultz, Ariz.

R. W. Prouty, formerly geologist with the Morenci branch of the Phelps-Dodge Corporation, has been appointed divisional mine foreman with the same company.

J. R. Thill is now master mechanic, Federal Lead Co., Flat River, Mo.

Timothy D. Walsh has resigned as superintendent of the Nevada Arizona Mines and accepted the position of superintendent of Tropicco Mining & Milling Co., Rosamond, Kern Co., Cal.

POSITIONS VACANT

Technical graduate wanted for metallurgical work in experimental laboratory of large New England manufacturing concern. A knowledge of metallography of steel is essential. Practical experience is desirable but not required. No. 305.

Man familiar with precipitating with the diamond drill core to act as foreman. No. 311.

Competent mining man to develop and take charge of mines in Peru. Property to be developed from start and equipped with thoroughly modern appliances to meet the increased production. Applicant must possess considerable mechanical ability and experience. No. 312.

Engineers and assistant engineers in forest production for National Defense work for the duration of war. Laboratory work conducted primarily by experimental and research methods, embracing principally investigations of mechanical and physical properties of wood, processes for the preservation of wood against decay and other destructive agents, practical problems of pulp and paper industry, and other industries utilizing wood by chemical means or otherwise. Assistance in this department of Government is urgently required in order to obtain maximum benefits from the investigation. Salary \$1860 to \$3000 for engineers; \$1200 to \$1800 for assistant engineers. No. 313.

Draftsman wanted for mechanical department of smelter plant producing spelter and sulphuric acid. No. 314.

Young engineer over draft age, single, to go to head office in Chile, S. A., of company operating several plants in nitrate district. Should have some experience in industrial cost analysis and efficiency work, in addition to general engineering experience. Salary \$3000 a year at commencement. No. 315.

Wanted—by well known company interested in acquisition of mining properties in Mexico, a thoroughly experienced geologist and examining engineer to take charge of mine examination work. Headquarters in Mexico City. Knowledge of Spanish indispensable. Give professional record and salary expected. No. 316.

Wanted—metallurgist with special experience in the concentration of ores by gravity, and particularly by flotation, and one who also has good mechanical engineering ability. The principal work will be of an experimental nature working out the best method of treatment for siliceous copper ores which will probably be suitable for flotation treatment. There will also be a considerable amount of work in connection with the improvement of the flotation work in the concentrator and in all probability the metallurgist would be expected to consult with the Mechanical Engineering Department and assist in the design of some new units for a concentrator which they expect to erect in the near future. The salary will depend upon the experience and proven ability of the applicant. No. 317.

Graduate mining engineer as assistant geologist for copper concern in the Southwest. Salary \$125 a month. Also experienced assistant chemist; salary \$150 a month. No. 318.

Engineer familiar with Western vein, stope, and patent surveying, who is also competent map draftsman. Single man preferred. High altitude. Salary \$200 a month. No. 319.

Mechanical draftsman experienced in ship calculations for immediate foreign service. For further information apply to American Engineering Service, Room 903, 29 West 39th Street, New York, N. Y. No. 321.

Electrical, heating, ventilating and topographical draftsman for Navy. Apply to American Engineering Service, Room 903, 29 West 39th Street, New York, N. Y. No. 322.

Draftsmen familiar with mine and smelter design. Salary \$200 a month. State experience and whether married. Position in Canada. No. 323.

ENGINEERS AVAILABLE

(Under this heading will be published notes sent to the Secretary of the Institute by members or other persons introduced by members.)

Member, age 33, single, desires position as mill superintendent or charge of mine and mill. Twelve years' milling, cyaniding and flotation in the southwest and Mexico. Will go anywhere. No. 458.

Member, mining engineer and geologist, graduated from mining college, age 27, single, exempt, with practice in metal mining, surveying of any kind, field geology and ore testing, desires to engage as geologist or mining engineer with a reputable concern in the west or east of U. S. Hard worker and reliable. No. 459.

Member, age 30, desires change of position. At present general superintendent of large producing silver property. Thorough experience from mucker and millman to superintendent. Married, technical graduate. No. 460.

Member, graduate mining and metallurgical engineer with four years' experience in design and operation, lead and copper smelter and concentrator work, desires connection with large concern. Available at a month's notice. No. 461.

Experienced mining engineer, Columbia School of Mines graduate, practical experience in drifting, shaft sinking and development work, also in mining, operating and equipping iron, copper and zinc properties. Married, age 32, available at once. Open for position as superintendent or assistant. No. 462.

Member, married, coal mine manager, experienced in pitching and faulted veins, coal washing, and coke burning, desires position, preferably in Alaska. A-1 references. No. 463.

Mining engineer with many years' practical experience as chief engineer and superintendent of coal mines is open for an engagement. Can furnish first class references. No. 464.

C. K. Huang, Chinese student, B. S. in mining from Pei-yang Univ., Tsintien, China, M. A. from Columbia University, specializing in ferrous metallurgy and inorganic chemistry research, desires to take up a position in some iron and steel plant in connection with the metallurgical and chemical researches. No. 465.

Member, age 33, married, desires position as mining engineer or engineering executive. Twelve years experience as mining engineer, geologist, and chief engineer of iron and copper properties. Experience in United States, Mexico and South America. Fluent Spanish. Technical graduate. Minimum salary \$3000. No. 466.

FORTHCOMING MEETINGS OF SOCIETIES

Organization	Place	Date 1918
American Society of Mechanical Engineers.....	Worcester, Mass.	June 4-7
American Institute of Chemical Engineers.....	Berlin, N. H.	June 19-22
American Concrete Institute.....	Atlantic City, N. J.	June 24-26
American Society for Testing Materials.....	Atlantic City, N. J.	June 25-28
American Institute of Electrical Engineers.....	Atlantic City, N. J.	June 26-28
New York Electrical Society, Annual Meeting...	New York, N. Y.	June
American Institute of Mining Engineers.....	Colorado	Sept. 2-7
National Association of Stationary Engineers....	Cincinnati, O.	Sept. 9-13
British Iron and Steel Institute, Autumn Meeting	London, Eng.	Sept. 12-13
National Exposition of Chemical Industries.....	New York, N. Y.	Sept. 23-28
American Chemical Society.....	Cleveland, O.	Sept.
National Petroleum Association.....	Atlantic City, N. J.	Sept.
American Electrochemical Society.....	Princeton, N. J.	Sept. 30- Oct. 2
Institute of Metals Division, A. I. M. E.....	Milwaukee, Wis.	Oct. 8-11
Iron and Steel Members, A. I. M. E.....	Milwaukee, Wis.	Oct. 8-10
American Foundrymen's Association.....	Milwaukee, Wis.	Oct. 7-12
American Museum of Safety and Sanitation, Exposition.....	St. Louis, Mo.	Oct. 7-12

PUBLICATION NOTES

INDEX TO TRANSACTIONS

After a delay of many months, which is very much regretted, but which, it is hoped, will be one means of insuring a volume of accuracy where accuracy is very important, the Institute now has for distribution copies of the index of Volumes XXXVI to LV, inclusive. This is more than a mere index of names of authors and titles of papers. Every important topic under consideration by author or discussor is introduced under such key-word as will enable an engineer to locate the desired information with the minimum expenditure of time. This index sells for \$3 in half morocco binding and \$2 in paper covers. With the index of Volumes I to XXXV (which sells for \$5 in half morocco and \$4 in paper covers), it forms a complete index of the first fifty-five volumes of the Institute's *Transactions*.

These collective indexes are very valuable to members of the Institute, enabling them to look up matters in their own library; if they have the volumes to which the indexes refer, they can get the information at once, and, if not, they can readily determine whether or not a visit to a nearby public library is desirable.

TRANSACTIONS WANTED

The Institute's stock of Volumes XXXI, LI, and LII has become much reduced by sales. If members have copies of these volumes which they can spare, the price of \$3 per volume will be paid for them, if in good condition. We shall appreciate it if members will pass the word along.

LIBRARY

AMERICAN SOCIETY OF CIVIL ENGINEERS

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

AMERICAN SOCIETY OF MECHANICAL ENGINEERS

AMERICAN INSTITUTE OF MINING ENGINEERS

UNITED ENGINEERING SOCIETY

HARRISON W. CRAVER, Director

The Library of the above-named Societies is open from 9 A. M. to 10 P. M. except on holidays. It contains about 70,000 volumes and 90,000 pamphlets, including sets of technical periodicals and publications of scientific and technical societies.

Members of the Institute, with few exceptions, are forced to spend a portion of their time in localities isolated from sources of information. To these the Library, through its Library Service Bureau, can render valuable service through correspondence; letters requesting information will receive especial attention. The Library is prepared to furnish references and photographic copies of articles on mining and metallurgical subjects; to determine the existence of mining maps, and to furnish general information on the geology and mineral resources of all countries.

All communications should be made as definite as possible so that the information received may be what is desired and not include collateral matter which may not be of interest. The time spent in searching for such collateral matter will be saved, and the information will be sent more promptly and in more usable shape.

Library Accessions

INCOMPLETE LIST CLASSIFIED BY SUBJECTS

Mining

- TREATISE ON MINE SURVEYING. Ed. 14. By Bennett H. Brough, revised and enlarged by Harry Dean. London, 1916.
- ONTARIO BUREAU OF MINES. Annual Report, 26th, 1917. Toronto, 1917.
- BROKEN HILL PROPRIETARY COMPANY, LTD. Report of 64th half-yearly ordinary general meeting, 1917. (Gift of company.)
- BROKEN HILL SOUTH SILVER MINING COMPANY. Reports, Statements of Accounts, etc., for half-year ended Dec. 31, 1917. Melbourne, 1917. (Gift of company.)
- DE BEERS CONSOLIDATED MINES. Annual Report, 29th, 1917. Kimberley, 1917.
- GOLDFIELD CONSOLIDATED MINES COMPANY. Annual Report. 11th Goldfield, 1917. (Gift of company.)
- MONTANA POWER COMPANY. Report for the year ending Dec. 31, 1917. New York, 1917. (Gift of company.)

Geology and Mineral Production

- GEOGRAPHIC DICTIONARY OF WASHINGTON. (Washington Geological Survey. Bulletin No. 17.) Olympia, 1917.
- THE BANKET. A study of the auriferous conglomerates of the Witwatersrand and the associated rocks. By Robt. B. Young. London, 1917.

- RIVISTA DEL SERVIZIO MINERARIO NEL 1916. Roma, 1917. (Gift of Ministero D'Agricoltura, Italy.)
- GOLD DEPOSITION IN THE BENDIGO GOLDFIELD, THE FACTORS INFLUENCING. Australia. (Advisory Council of Science and Industry. Bulletin No. 4.) Melbourne, 1917. (Gift of Advisory Council of Science and Industry.)
- QUEBEC. Department of Colonization, Mines and Fisheries. Preliminary Statement on the mineral production in the Province during 1917. (English and French.) Quebec, 1918.

Chemistry

- TRATTATO DI CHIMICA ANALITICA APPLICATA. Vol. I. By Vittorio Villavecchia. Milano, 1916.
- CHEMISTRY OF LINSEED OIL. By J. Newton Friend. London, 1917.
- CARBONIZATION OF ILLINOIS COALS IN INCLINED GAS RETORTS. (Illinois State Geological Survey. Bulletin 20, Coöperative Coal Mining Series.) Urbana, 1918.

Vocational Education

- TRAINING OF TEACHERS FOR OCCUPATIONAL THERAPY FOR THE REHABILITATION OF DISABLED SOLDIERS AND SAILORS. Letter from the Federal Board for Vocational Education, transmitting in response to a Senate resolution of Jan. 27. Washington, 1918. (Gift of U. S. Federal Board for Vocational Education.)
- VOCATIONAL REHABILITATION OF DISABLED SOLDIERS AND SAILORS. Letter from the Federal Board for Vocational Education. Washington, 1918. (Gift of U. S. Federal Board for Vocational Education.)
- REHABILITATION AND VOCATIONAL REEDUCATION OF CRIPPLED SOLDIERS AND SAILORS. Letter from the Secretary of War transmitting in response to a Senate resolution of Jan. 31, 1918. Washington, 1918. (Gift of U. S. Federal Board for Vocational Education.)

Miscellaneous

- PHILIPPINE JOURNAL OF SCIENCE. Contents and Index. Vols. 1-10, 1906-1915. Manila, 1917. (Gift of Philippine Bureau of Science.)
- REFRACTORY MATERIALS; THEIR MANUFACTURE AND USES. By Alfred B. Searle. London, 1917.
- LAND AND MARINE DIESEL ENGINES. Ed. 2. By Giorgio Supino. London, 1917.
- DESIGN AND CONSTRUCTION OF INDUSTRIAL BUILDINGS. By Moritz Kahn. London, 1917.
- FIRE IN A REINFORCED CONCRETE WAREHOUSE, FAR ROCKAWAY, NEW YORK. By I. H. Woolson. London, 1918.
- THE PRESERVATION OF WOOD. By A. J. Wallis-Taylor. London, n.d.
- COTTON PRODUCTION AND DISTRIBUTION, 1916-17. (U. S. Bureau of the Census, Bulletin 135.) Washington, 1918.
- TECHNOLOGY OF SALT MAKING IN THE UNITED STATES. By W. C. Phalen. (U. S. Bureau of Mines. Bulletin No. 146.) Washington, 1917. (Gift of author.)
- THE WORLD SHIPPING PROBLEM. (Gift of American Society of Mechanical Engineers.)
- WAR PROFITEERING. Some practical aspects of its control. By Eugene Meyer, Jr. Washington, 1917. (Gift of author.)
- MARINE INSURANCE (HULL). An address delivered before the 149th meeting of the Insurance Society of New York, Feb. 26, 1918. By Benjamin Rush. (Gift of Insurance Society of New York.)
- THE GERMAN UNION OF TECHNICAL AND SCIENTIFIC SOCIETIES. By Robert Hadfield. January, 1918. (Gift of Sir Robert Hadfield.)
- NEW YORK CITY BOARD OF WATER SUPPLY. Information for bidders, forms of bid, contract, bond and certificates, specifications and drawing for making, testing and cleaning borings around the shafts of the City Tunnel of the Catskill aqueduct in the City of New York. (Contract 194.) 1918. (Gift of Board of Water Supply of the City of New York.)
- WISCONSIN-RAILROAD COMMISSION. Opinions and Decisions. Vol. 18, Je. 2, 1916-March 9, 1917. Madison, 1917. (Gift of A. D. Flinn.)
- UNIVERSAL DIRECTORY OF RAILWAY OFFICIALS, 1917. London, 1917.

Book Notices

Unless otherwise specified, books in this list have been presented by the publishers. The Institute does not assume responsibility for any statements made; these are taken from the preface or the text of the book.

All the books listed may be consulted in the Engineering Societies Library.

AIRCRAFT MECHANICS HANDBOOK. A collection of Facts and Suggestions from Factory and Flying Field to Assist in Caring for Modern Aircraft. By Fred H. Colvin. 1st edition. N. Y., McGraw-Hill Book Company, Inc.; Lond., Hill Publishing Company, Ltd., 1918. 402 pp., 193 illus., 28 tab., 7 × 5 in., flexible cloth, \$3.

A manual of the best practice in inspecting, adjusting and repairing airplanes, prepared for use by the machinists and riggers who are now being trained. Describes the construction, erection and testing of the planes, the various engines in use and the methods of caring for them. An account of the Canadian Training Camp at Borden is also given. Useful tables and a glossary are included.

MANUAL OF MILITARY AVIATION. Prepared for the use of Personnel of Aircraft Troops of the Army, National Guard and Reserve Corps; Officers of the Army, National Guard and Reserve Corps; Members of Military Training Camps; and Airmen in General. By Hollis Leroy Müller. Menasha, Wis., George Banta Publishing Co. (copyright 1917). 308 pp., 38 illus., 8 × 5 in., cloth, \$2.50.

Contains the theoretical information necessary for efficient military aviation service. Intended for use as a text-book and as a reference work.

AVIATION CHART. Location of Airplane Power Plant Troubles Made Easy. By Victor W. Pagé. N. Y., The Norman W. Henley Publishing Co., 1918. 46 × 32 in., paper, 50 cts.

A large chart outlining all parts of a typical airplane power plant, showing the points where trouble is apt to occur and suggesting remedies for the common defects. Intended especially for aviators and aviation mechanics on school and field duty.

FIELD ARTILLERYMAN'S GUIDE. 3 Inch Gun, 4.7 and 6 Inch Howitzer. Prepared by the officers of the 108th (2d Pa.) Field Artillery. 2d revised edition. Phila., P. Blakiston's Son & Co. (copyright 1918). 381 pp., 102 illus., 3 pl., 31 tab., 7 × 4 in., cloth, \$1.75.

A pocket guide intended to serve the immediate needs of field artillerymen in the United States Army, by presenting the fundamentals of their duties.

MACHINE SHOP PRACTICE. By William B. Hartman. N. Y. and Lond., D. Appleton & Co., 1917. 247 pp., 141 illus., 4 pl., 10 tab., 7 × 5 in., cloth, \$1.10.

A presentation of the elementary principles of machine shop practice, intended for the instruction of beginners. Mathematical calculations are confined to the use of simple arithmetic.

TEXT-BOOK OF ADVANCED MACHINE WORK. Prepared for Students in Technical, Manual Training, and Trade Schools, and for the Apprentice and the Machinist in the Shop. By Robert H. Smith. 4th edition, revised and enlarged. Bost., Industrial Education Book Co. (copyright 1916). 648 pp., 680 illus., 44 tab., 8 × 5 in., cloth, \$3.

A continuation of the author's "Principles of Machine Work." This volume treats of engine lathe work, drilling and boring machines, grinding, planing, milling, gear cutting and tool making. Careful explanations are given for each variety of work.

COLD DRAWN STEEL. Bar Weights of Rounds, Flats, Hexagons and Squares; Weight Tables for Plates; Metric Conversion Tables; Cold Drawn and Hot Rolled Extras, and other Miscellaneous Tables (Cover title: Book of Weights). Issued by the Peerless Drawn Steel Co. Massillon, O., The Peerless Drawn Steel Co., 1918. 145 pp., 52 tab., 8 × 5 in., flexible leather, \$3.

Instead of giving only the weight per foot of steel bars of various sizes, this book gives the totals for bars of all the usual lengths in feet. A number of other useful tables are added.

COMPLETE LIST OF BASE PRICES, DIFFERENTIALS AND EXTRAS ON IRON, STEEL AND NON-FERROUS PRODUCTS. Fixed under Government Supervision. Cleveland, Penton Publishing Co. (copyright 1918). 42 pp., 8 × 6 in., paper, \$2.

A convenient summary of the Government prices. Prepared by the Iron Trade Review and presented to subscribers to that journal.

FORGING. Manual of Practical Instruction in Hand Forging of Wrought Iron, Machine Steel, and Tool Steel; Drop Forging; and Heat Treatment of Steel, Including Annealing, Hardening, and Tempering. By John Jernberg. Chic., American Technical Society, 1917. 131 pp., 206 illus., 2 pl., 3 tab., 8 × 6 in., cloth, \$1.

A concise account, intended primarily for students. Describes the method and tools used in hand forging, as well as the usual shop practice in hardening, annealing and tempering steel.

HANDBOOK OF HYDRAULICS. For the Solution of Hydraulic Problems. By Horace Williams King. 1st edition. N. Y., McGraw-Hill Book Company, Inc.; Lond., Hill Publishing Company, Ltd., 1918. 16 + 424 pp., 91 illus., 112 tab., 2 diagrams, 7 × 4 in., flexible cloth, \$3.

The author has attempted to simplify the work of the hydraulic engineer by studying critically the empirical formulas which have been devised and selecting those which are of value. These are presented with a description of their limitations and are accompanied by the necessary tables of coefficients. The twofold purpose of securing an accuracy consistent with the best experiments and of simplifying calculations has been kept in mind throughout the book.

INTERNAL COMBUSTION ENGINE MANUAL. By F. W. Sterling. 4th edition. Wash., R. Beresford, 1917. 168 pp., 10 × 6 in., cloth, \$2.

This manual, representing the course on internal combustion engines given at the U. S. Naval Academy, has been rewritten, enlarged and brought up to date. It now covers the theory and practice of these engines without including mathematical demonstrations and formulas. Particular attention is given to the engines used by the Navy and to aviation engines.

METALLURGICAL CALCULATIONS. By Joseph W. Richards. N. Y., McGraw-Hill Book Company, Inc.; Lond., Hill Publishing Company, Ltd., 1918. 23 + 675 pp., tab., 10 × 7 in., cloth, \$5.

A convenient one-volume edition of the work, in which errors occurring in earlier ones have been corrected and new physical and chemical data have been added.

POWER STATIONS AND TRANSMISSION. A Comprehensive Treatise on Electric Power Station Equipment, Design, and Management, and the Erection and Maintenance of Proper Transmission Lines. By George C. Shaad. Chic., American Technical Society, 1917. 180 pp., 50 illus., 3 pl., 10 tab., 8 × 6 in., cloth, \$1.

Presents concisely the important features of the topic. The treatment is largely descriptive and non-mathematical.

THE PRINCIPLES, OPERATION AND PRODUCTS OF THE BLAST FURNACE. By J. E. Johnson, Jr. 1st edition. N. Y., McGraw-Hill Book Company, Inc.; Lond., Hill Publishing Company, Ltd., 1918. 15 + 551 pp., 173 illus., 23 tab., 9 × 6 in., cloth, \$5.

A thorough, detailed discussion of the operation of the blast furnace, including both the theoretical principles and the practice of the present day. Completes the author's treatise on the manufacture of pig-iron, begun in his work entitled "Blast Furnace Construction."

STATE SANITATION. A Review of the Work of the Massachusetts State Board of Health. By George Chandler Whipple. Vol. 2. Cambridge, Harvard University Press; Lond., Humphrey Milford, 1918. 452 pp., 17 illus., 3 pl., 1 por., 60 tab., 10 × 7 in., cloth, \$2.50.

This volume contains abstracts of the leading articles on subjects relating to preventive medicine, hygiene and sanitation which are scattered through the annual and special reports of the Massachusetts State Board of Health published between 1869 and 1914. In addition, thirty-four of the most important contributions to sanitation are reprinted, with some abridgment.

THE PRINCIPLES OF SANITARY TACTICS. A Handbook on the Use of Medical Department Detachments and Organizations in Campaign. By Edward Lyman Munson. Menasha, Wis., George Banta Publishing Co. (copyright 1917) 305 pp., 13 maps, including 2 folded maps in covers, 8 × 5 in., cloth, \$2.15.

The author's desire has been to provide a text-book which will standardize the methods of instructing line and medical officers in the tactical use of the sanitary service with troops in campaign and will also give a thorough grounding in the fundamentals of sanitary tactics as a whole.

THE SCIENCE OF MANAGEMENT. By Frederic A. Parkhurst. Cleveland (the author) (copyright 1918) 203 pp., 7 tab., 9 × 6 in., cloth, \$3.

A text-book prepared to accompany the author's course of thirty lectures, delivered during 1917-18 at the Case School of Applied Science.

SCIENTIFIC INDUSTRIAL EFFICIENCY. By Dwight T. Farnham. Chic., Brick and Clay Record, 1917. 101 pp., 34 illus., 10 × 6 in., cloth, \$2.

In this book the author has endeavored to describe some applications of scientific management which have come under his observation during his experience as an engineer and executive. The examples given are chiefly taken from the clay products industry.

WAR ADMINISTRATION OF THE RAILWAYS IN THE UNITED STATES AND GREAT BRITAIN. By Frank Haigh Dixon and Julius H. Parmelee. (Carnegie Endowment for International Peace, Division of Economics and History. Preliminary Economic Studies of the War.) N. Y., Oxford University Press, 1918. 13 + 155 pp., 10 × 7 in., paper, \$1. (Gift of the Carnegie Endowment for International Peace.)

An account of the methods used in the two countries and of the results achieved prior to December, 1917, during the period when the American railways were voluntarily cooperating with each other. The authors present a simple narrative, without attempting to draw conclusions.

WAR TIME CONTROL OF INDUSTRY. The Experience of England. By Howard L. Gray. N. Y., The Macmillan Company, 1918. 15 + 307 pp., 8 × 5 in., cloth, \$1.75.

A summary of the development and status of governmental control of industry in Great Britain, arranged to show its successive stages. Part of the information was collected for the Commercial Economy Division of the Council of National Defense. The book concludes with a comparison of English and American experience.

ARTIFICIAL DYE-STUFFS. Their Nature, Manufacture, and Uses. By Albert R. J. Ramsey and H. Claude Weston. Lond., George Routledge & Sons, Ltd.; N. Y., E. P. Dutton & Co., 1917. 212 pp., 24 illus., 9 × 6 in., cloth, \$1.60. (Gift of E. P. Dutton & Co.)

A brief introductory work on the artificial dye-stuff industry, written for students and business men with little knowledge of organic chemistry, in which the industrial processes of the manufacture of dye-stuffs, and the nature of the substances used, are explained at some length.

COAL GAS RESIDUALS. By Frederick H. Wagner. 2d edition, revised and enlarged. N. Y., McGraw-Hill Book Company, Inc.; Lond., Hill Publishing Company, Ltd., 1918. 13 + 244 pp., 45 illus., 12 pl. (10 folded) 7 diagrams, 32 tab., 9 × 6 in., cloth \$2.50.

The chief additions to this edition discuss the process of tar distillation and tar products, and give further information on the product derived from spent oxide, the production of nitric acid, naphthalene, benzol and toluol. A chapter on the manufacture of sulfuric acid from spent oxide has also been added, and the typographical errors in the first edition have been corrected.

AGRICULTURAL BACTERIOLOGY. A Study of the Relation of Germ Life to the Farm with Laboratory Experiments for Students. Microorganisms of Soil, Fertilizers, Sewage, Water, Dairy Products, Miscellaneous Farm Products and of Diseases of Animals and Plants. By H. W. Conn. 3d edition, revised by Harold Joel Conn. Phila., P. Blakiston's Son & Co. (copyright 1918) 10 + 357 pp., 63 illus., 8 × 6 in., cloth, \$2.

The third edition has been brought up to date by the inclusion of the advances in bacteriological knowledge since the previous edition.

MECHANICS OF THE HOUSEHOLD. A Course of Study Devoted to Domestic Machinery and Household Mechanical Appliances. By E. S. Keene. N. Y., McGraw-Hill Book Company, Inc.; Lond., Hill Publishing Company, Ltd., 1918. 10 + 391 pp., 273 illus., 11 tab., 8 × 6 in., cloth, \$2.50.

This book is intended to be a presentation of the physical principles and mechanism employed in the equipment that has been developed for domestic convenience. Equipment for heating, ventilating, water supply, sewage disposal, lighting, etc., is described.

THE MODERN MILK PROBLEM. In Sanitation, Economics, and Agriculture. By J. Scott MacNutt. N. Y., The Macmillan Company, 1917. 11 + 258 pp., 2 illus., 16 pl., 9 × 6 in., cloth, \$2.

Written to supply a convenient survey of the main aspects of the milk problem, which will emphasize the practical and economic as well as the sanitary factors involved. Intended for health officials, dairymen, legislators and others interested in better milk supplies.

RADIO-TELEPHONY. By Alfred N. Goldsmith. N. Y., The Wireless Press., Inc. (copyright 1918) 247 pp., 226 illus., 9 × 6 in., cloth, \$1.25.

The author has attempted in this work to give a full description of present methods of radio-telephony and of the various types of apparatus employed. The first systematic exposition of the subject to appear since 1907.

GALVANIZING AND TINNING. A Practical Treatise on the Coating of Metal with Zinc and Tin by the Hot Dipping, Electro Galvanizing, Sherardizing and Metal Spraying Processes, with Information on Design, Installation and Equipment of Plants. By W. T. Flanders. N. Y., David Williams Co., 1916. 350 pp., 142 illus., 3 charts, 5 tab., 9 × 6 in., cloth, \$4. (Gift from the U. P. C. Book Co.).

Discusses the various processes in a practical way, describing the machinery, materials and operations in detail. Intended as a guide in the installation and operation of galvanizing and tinning plants.

ELECTRODYNAMIC WAVE-THEORY OF PHYSICAL FORCES. Announcing the Discovery of the Physical Cause of Magnetism, of Electrodynamic Action, and of Universal Gravitation . . . Vol. 1, Bulletins 1 to 6 inclusive. By T. J. J. See. Lynn, Mass., Thomas P. Nichols & Son Co.; Lond., William Wesley & Son; Paris, A. Hermann et Fils, 1917. 14 + 158 pp., 21 diagrams, 4 pl., 1 chart, 6 tab. (1 folded) 12 × 10 in., paper, \$5.

In these bulletins Dr. See presents his hypothesis that magnetism, electrodynamic action and universal gravitation are due to waves propagated with the velocity of light through the free ether and at slower rates through solid masses. The author believes that his investigations have finally solved the problem of the nature and mode of propagation of physical forces.

ELECTRICAL MEASUREMENTS. A Practical Handbook Covering the Design and Construction of Measuring Instruments and their Uses in Measurement of Current, Resistance, and Commercial Power, with Special Reference to Watt-hour and Maximum Demand Meters. By O. J. Bushnell and A. G. Turnbull. Chic., American Technical Society, 1914. 171 pp., 139 illus., 2 pl., 8 × 6 in., cloth, \$1.

The authors' aim has been to supply an adequate description of the instruments and methods used for the measurement of electrical energy, and to show by diagrams exactly how meters should be connected under all conditions.

CREATING CAPITAL. Money-making as an Aim in Business. By Frederick L. Lipman. Bost. and N. Y., Houghton Mifflin Co., 1918. 71 pp., 7 × 5 in., cloth, 75 cents.

HIGHER EDUCATION AND BUSINESS STANDARDS. By Willard Eugene Hotchkiss. Bost. and N. Y., Houghton Mifflin Co., 1918. 109 pp., 7 × 5 in., cloth, \$1. (Gift of the University of California Press.)

Two essays delivered at the University of California on the Weinstock Foundation, established for the discussion of various phases of the moral law in its bearing on business life under the new economic order.

MEMBERSHIP

NEW MEMBERS

The following list comprises the names of those persons who became members during the period of Apr. 10, 1918, to May 10, 1918.

- BALLARD, JOHN I. Supt., Cable Mining Corp'n., Cable, Mont.
 BURKMAN, JOHN M. F., Constr. Engr., U. S. Smelt. Refin. & Min. Co.,
 Care University Club, Mexico City, D. F.
 CALLEN, ALFRED COPELAND, Head, Mining Engineering Dept.,
 West Virginia University, Morgantown, W. Va.
 CHADWICK, LAWRENCE, Chem., Mt. Elliott Copper Co., Ltd., Selwyn, via Townsville,
 North Queensland, Australia.
 CODY, FRANK W., Skimmer, Reverberatory Furnace, Arizona Copper Co.,
 Clifton, Ariz.
 COOLBAUGH, MELVILLE F., Prof. of Chem., Colorado School of Mines, Golden, Colo.
 DODGE, ALLAN WAYNE. The Dodge Agency, 104 East Iron Ave., Salina, Kans.
 DONNELLY, LEONARD G., Pet. Geol., Sinclair Oil & Gas Co., Sinclair Bldg.,
 Tulsa, Okla.
 DUCE, JAMES TERRY, Geol., Sec., Colorado State Bureau of Mines, Denver, Colo.
 FISHER, FRANK LORING, Min. Engr., Anaconda Copper Min. Co., 513 Hennessy Bldg.,
 Butte, Mont.
 GOSROW, ROLFE CLEVELAND, Electrometallurgist, North American Co.,
 203 Juneau Ave., Milwaukee, Wis.
 GOTTSCHALK, CHARLES. Chief Engr., Union Colliery Co., Du Quoin, Ill.
 JEQUIOR, HENRI LOUIS, Chief Met., Société Minière et Métallurgique de Penarroya,
 Penarroya, Prov. de Cordoba, Spain.
 KESHIAN, H. G., Chem., Metallographer, Waterbury Mfg. Co.,
 58 Central Ave., Waterbury, Conn.
 KEYES, HARMON EDWARD, Assayer & Met. Chem., Consolidated Min. & Smelt. Co.,
 of Canada, Trail, B. C., Canada.
 KNICKERBOCKER, RAY G. Care Missouri School of Mines, Rolla, Mo.
 KNOWLTON, J. W., Chief, Chem. & Geol. Dept., West Virginia Coal & Coke Co.,
 Elkins, W. Va.
 KOCH, OTTO, Met. Engr., The Amelia Nitrate Co., Ltd., Negreiros via Iquique,
 Chile, S. A.
 MAHONEY, J. N., Engr., Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.
 NORMAN, THOMAS STANLEY, Asst. Mgr. of Metals, United Alkali Co., Ltd.,
 Lyndhurst, Runcorn, Cheshire, England.
 OTSUBO, TERUO, Min. Engr., Osaruzawa Mine, Kazuno-Gun, Akita-Ken, Japan.
 PALÉN, A. G. PAUL, Min. Engr., Aktiebolaget Kopparextraktion, Stockholm, Sweden.
 PICK, ALFRED WALLIS, Mech. Engr. 614-15, Ideal Bldg., Denver, Colo.
 POULSEN, MAGNUS, Chief Engr., Société Belge Industrielle et Minière du Katanga,
 36 Avenue Neuilly, Paris, France.
 PRICE, S. S., Oil Geol. 307 Kennedy Bldg., Tulsa, Okla.
 QUINN, CLEMENT K. Alworth Bldg., Duluth, Minn.
 ROBERTS, NEWELL W., Vice-pres., International Coal Products Corp'n.,
 24 Broad St., New York, N. Y.
 ROBINSON, NORMAN, Civil Engr., Vickers Ltd., Vickers House, Broadway,
 Westminster, London, England.
 SEAMAN, HALLOCK W. Pres., Trojan Min. Co., 719 Rookery Bldg., Chicago, Ill.
 SHIGEMATSU, YASUKAZU, Mngng. Director, Metal Min. Dept., Mitsubishi Co.,
 Tokyo, Japan.
 SMITH, VELEAIR C., Asst. Chem., Ledoux & Co., 99 John St., New York, N. Y.
 SPROAT, ERL LANE, Min. Engr., Moose Mountain Ltd., Sellwood, Ont., Canada.
 STILLMAN, FREDERICK O., Research Met., Mea Bay Iron Co., Waverly Ave.,
 Melrose, Mass.
 STRICK, A. E., Min. Supt., Mount Elliott, Ltd., Great Australia Mine,
 Cloncurry, Queensland, Australia.
 WEEKS, F. D., Min. Geol. & Engr., U. S. Smelt. Refin. & Min. Exploration Co.,
 1012 Newhouse Bldg., Salt Lake City, Utah.

WENDELL, CARL A., Chief Engr., American Ore Reclamation Co., 71 Broadway,
New York, N. Y.
WISSER, EDWARD HOLLISTER, 2d Lieut., Engrs. Reserve Corps, Headquarters,
Hawaiian Dept., Honolulu, H. T.
WYANT, FRANK A. Division Engr., United Coal Corp., Pittsburgh, Pa.

Associates

ARMITAGE, PAUL. Lawyer, 233 Broadway, New York, N. Y.
MOILES, EARLE D. Mech. Engr., Sunnyside Min. & Mill. Co., Eureka, Colo.

Junior Associates

CONLEY, WILLIAM A. Student, Colorado School of Mines, Golden, Colo.
GILMAN, CHARLES GRAFELY. Student, Lehigh University, South Bethlehem, Pa.
MEKLER, LEV A. Student, University of California, Berkeley, Cal.
SCHEMMEL, JULIUS. Min. Engr., Pickands Mather & Co., Keewatin, Minn.
STOUT, HERBERT A., Student, So. Dakota State School of Mines, Rapid City, S. D.

Change of Status, Junior to Member

ARMSTRONG, J. A. B., Andes Exploration Co. of Maine, Casilla 290, Arequipa, Peru.
Total Membership, May 10, 1918 6767

CANDIDATES FOR MEMBERSHIP

APPLICATION FOR MEMBERSHIP.—The Institute desires to extend its privileges to every person to whom it can be of service. On the other hand, it is not desirable that persons should be admitted to membership in classes for which they are not qualified. Members of the Institute can be of great service if they will make a practice of glancing through the list of applicants and promptly notifying the Committee on Membership, or the Secretary of the Institute, of any persons whom they think should not be classified in accordance with the list given.

Applications Lacking Endorsement

Applications for membership have been received from Mr. Hogg, Mr. Schuler and Mr. Teale, whose records are given below. These applications lack the necessary number of endorsers, but since these candidates live at some distance from the headquarters of the Institute, their records are published here in order that any members who are acquainted with them may be advised of the circumstances and may have an opportunity of writing to the Secretary endorsing these candidates.

Members

James Hogg, Euboea, Greece.

Proposed by P. D. Ahier.

Born 1871, Lanarkshire, Scotland. Hutchesontown Grammar School, Glasgow. Glasgow Technical College. Member, Institute of Min. and Met. and Federated Institute of Min. Engrs. 1890-95, Min. Apprentice, McCreaths & Stevenson, Glasgow. 1895-97, Underground Colliery Mgr., Podmore Hall Collieries, Staffordshire. 1897-1904, Mines Mgr., Aznalcollar Mines, Seville Sulphur & Copper Co., Seville, Spain. 1904-11, Mgr., Heredia Lead Mines, Linares, Spain. 1911-17, Mgr., Anglo-Greek Magnesite Co., Ltd.

Present position: Director and Mgr., Anglo-Greek Magnesite Co., Ltd.

Herman Schuler, Vallenar, Chile.

Proposed by Philip R. Gleason, John P. Chadwick.

Born 1878, Schaffhouse. 1898, Grad., Lyceum of Winterthur, Switzerland. 1902, Grad., Polytechnical School of Zurich, Switzerland, C. E. 1902-04, Civil engr., Swiss Govt. 1904-06, With Harkort Co., steel construction, Duisburg, Germany. 1906-07, Hydraulic work in Silesia for German Govt. 1907-09, Min. engr., Naltagua Copper Co., Chile. 1909-12, Railroad constructor for Chilian Govt.

Present position—1912 to date: Mine Operator, Vallenar Dist.

Associate

James Willie Teale, Euboea, Greece.

Proposed by P. D. Ahier.

Born 1882, Leeds, England. 1886-90, General education, Leeds School Board. 1890-95, Ossett School, near Wakefield. 1895-1902, Ossett Technical School, full engr. course, science and art, South Kensington, obtaining Advanced Certificates. Correspondence courses. 1898-1903, Apprenticed to Bradley & Craven Ltd., Engrs., Iron & Brass Foundries, Wakefield, England. 1904-06, Asst. to mech. and elec. engr., Old Roundwood Collieries, Wakefield, England. 1907, Asst. to mech. and elec. engr., Hoyland Lilkstone Collieries, Ltd., Barnsley. 1908, Asst. to mech. and elec. engr., Bullcroft Main Collieries, Doncaster, England.

Present position: Mech. Engr., The Anglo-Greek Magnesite Co., Ltd.

The following persons have been proposed during the period Apr. 10, 1918, to May 10, 1918, for election as members of the Institute. Their names are published for the information of Members and Associates, from whom the Committee on Membership earnestly invites confidential communications, favorable or unfavorable, concerning these candidates. A sufficient period (varying in the discretion of the Committee, according to the residence of the candidate) will be allowed for the reception of such communications, before any action upon these names by the Committee. After the lapse of this period, the Committee will recommend action by the Board of Directors, which has the power of final election.

Members

Edwin Barnhart, Sparrow's Point, Md.

Proposed by W. L. Cumings, M. L. Jacobs, F. D. Carney.

Born 1881, Sunbury, Pa. High School. Correspondence and private instruction in chemistry and metallurgy. 1900-06, Laboratory asst.; 1906-10, Chief chemist; 1910-14, Supt. byproduct coke ovens. 1914-16, Experimental engr., Maryland Steel Co. 1916-18, Experimental engr., Bethlehem Steel Co.

Present position: Engr. of Tests, Bethlehem Steel Co.

Carleton Perkins Browning, Britannia Beach, B. C.

Proposed by E. H. Hamilton, H. W. Hardinge, Harvey S. Mudd.

Born 1890, Norwich, Conn. 1908-13, Columbia Univ. School of Mines, E. M. 1910, Engr. staff, Cap Cod Construction Co., on Cape Cod Canal. 1911, Millman, Miami Copper Co., Miami, Ariz. 1912 (Summer), Engr. staff, Tennessee Copper Co., Copperhill, Tenn. 1913-14, Engr., Britannia Min. & Smelt. Co., Ltd., Britannia Beach, B. C.

Present position—1915 to date: Gen'l Supt., Britannia Min. & Smelt. Co.

George Byers Clark, Denver, Colo.

Proposed by L. V. Emanuel, H. H. Utley, Lyon Smith.

Born 1878, Chicago, Ill. 1897, Grad., Denver High School. 1901, Colorado School of Mines, E. M. 1901-02, Surveying party, Colorado Fuel & Iron Co. 1902, Various duties around small mines near Idaho Springs; surveying for G. R. De Nise, San Juan region, Colo. 1902-03, Various small complete jobs, draughting, surveying, mine examining, etc. 1903-04, Engrg. Dept.; 1904-08, Assayer, Eilers Plant, American Smelt. & Refin. Co., Denver and Pueblo, Colo. 1908, Post Grad., Colorado School of Mines. 1908-09, Traveling chem., Colorado Smelters. 1909-10, Chief

Chem., Durango Plant, American Smelt. & Refin. Co. 1910-15, Conducted custom assay office and chem. lab., at Pueblo, Colo., under name of Clark & Stone. 1915-17, Chem., River Smelt. & Refin. Co., Florence, Colo.

Present position—1917 to date: Asst. Valuation Engr., Colorado & Wyoming Ry. Co.

Bert Morse Concklin, Hibbing, Minn.

Proposed by Carl Zapffe, J. C. Agnew, Ben A. Mizen.

Born 1881, Wichita, Kans. 1893-1902, Common grade school; high school, Milwaukee, Wis. 1902-05, Univ. of Wisconsin. 1902-05 (Summers), Timekeeper, asst. roadmaster, Milwaukee Street Ry. 1905-10, Engr., pit foreman, Morris-Hull-Rust mines, Oliver Iron Min. Co., Hibbing, Minn. 1910-13, Ch. engr., Western Dist.; 1913-17, Dist. supt., Arthur Iron Min. Co., Calumet, Minn. 1917-18, Dist. supt., Interstate Iron Co., Calumet, Minn.

Present position: Ch. Engr., Range Great Northern Iron Ore Properties.

Ralph D. Crawford, Boulder, Colo.

Proposed by Victor G. Hills, H. E. Collbran, W. W. Case, Jr., James Terry Duce.

Born 1873, Peotone, Ill. 1902-07, Student of chemistry, mineralogy and geology, Univ. of Colorado, B. A., M. A. 1910-11, Grad. student of geology and mineralogy, Yale Univ., Ph. D. 1906 (Summer), Field asst., U. S. Geol. Survey. 1907-09, Asst., Colorado Geol. Survey. 1909-17, Geol., Colorado Geol. Survey. 1907-08, Instructor in geology, Univ. of Colorado. 1908-14, Asst. prof. of geology, Univ. of Colorado.

Present position: Professor of Mineralogy and Petrology, Univ. of Colorado.

Louis Leverett Davis, Denver, Colo.

Proposed by Charles W. Henderson, Arthur J. Hoskin, Robert M. Keeney.

Born 1888, Kyoto, Japan. 1908-10, Colorado School of Mines. 1912-13, Armour Institute of Technology. 1910-11, Matchless mine, Leadville, Colo. 1911, Iron-Silver Min. Co., Leadville, Colo. 1911-12, Chem., National Boiler Specialties Co. 1913-14, Chem. engr., National Boiler Specialties Co. 1914-15, Mining in various districts, also consulting engineering work. 1916-17, Mgr., The Commonwealth Min. Co., and Cons. Engr.

Present position: Mgr. and Treas., The Commonwealth Min. Co.

Robert Sewart Davis, Milton, Pa.

Proposed by S. H. Ball, Lucius W. Mayer, Allen H. Rogers, Knox Taylor.

Born 1877, Milton, Pa. 1893, Grad., Milton High School. 1895, Williston Seminary, Easthampton, Mass. 1895-99, Princeton Univ., B. S. 1899-1900, Chem., Danville Bessemer Co., Danville, Pa., and National Steel Co., Mingo Jc., Ohio. 1900-1905, Chem. lab., P. R. R., Altoona, Pa. 1906-07, Chem., Old Dominion Copper Min. & Smelt. Co., Globe, Ariz. 1907, Sampler, Cananea Cons. Copper Co., Cananea, Mex. 1908, Engr. and chem., American Smelters Security Co., Velardena, Mexico. 1909, Opening and sampling, La Cruz mine and Blalack mine, Mexico, Exam. engr., Yaqui Min. Co., La Dura, Mexico, and Engr., General Dev. Co. 1910-11, Engr. and min. supt., Calumet & Sonora, Cananea, Mexico. 1912, Asst. engr., General Development Co., Shafter, Tex. 1913, Engr., Puertecitos, Cananea Cons. Copper Co. 1914-17, Charge of diamond drilling, Cia. Minière et Forestière du Congo.

Present position: Diamond drilling in Missouri, Rogers, Mayer & Ball.

Berton Henry DeLong, Reading, Pa.

Proposed by W. B. Kunhardt, J. Heber Parker, Joseph S. Pendleton.

Born 1885, Taylor, N. Y. 1898-1901, High School, McGraw, N. Y. 1902-04, State Normal School, Cortland, N. Y. 1905-06, Allegheny College, Meadville, Pa. 1906-09, Cornell Univ., Ithaca, N. Y., A. B. 1904-05, Principal, High School, Freeville, N. Y. 1909-10, Chemist, Stanley Works, New Britain, Conn.

Present position—1910 to date: Asst. Met., The Carpenter Steel Co.

Casimiro Domeyko Alamos, Santiago, Chile.

Proposed by A. T. Ward, L. T. Higgins, W. S. Bishop.

Born 1892, Santiago, Chile. 1909, Engr. Degree, School of Mines, Copiapó, Chile. 1910-12, Worked for myself. 1912-14, Engr., Cia. Oro de Rancagua. 1914-17, Asst. in father's engineering office.

Present position: Engr., Cia Huanchaca, Bolivia, S. A.

Mehring Vere Eardley, Joplin, Mo.

Proposed by G. B. Corless, P. B. Butler, W. H. Eardley.

Born 1886, Salt Lake City, Utah. 1900-01, High School, Baker, Ore. 1901-03, High School, Salt Lake City. 1903-07, State School of Mines, Univ. of Utah, B. S. 1907-08, General Electric Test Course, Schenectady, N. Y. 1907, Instructor, laboratory, Univ. of Utah; during G. E. Test Course, asst. supt. 1907-09, Govt. Dept., asst. foreman, Transformer Dept., ch. switchboard instructor. 1910, Field construction engr., New England States, General Electric Co. 1910-12, Supt. construction and operation, Knight Cons. Power Co., Provo, Utah. 1912-14, Supt. of maintenance and transmission, Utah Power & Light Co., Salt Lake City. 1914-15, Gen. mgr., Nav Aug Min. Co., Salt Lake City, Utah. 1915-17, Gen. mgr., Vesuvius Min. Co., Carthage, Mo. 1917-18, Mgr., Standard Zinc Lead Min. Co., Baxter, Kans.

Present position: Asst. Mgr., Chanute Spelter Co.

Harold W. Fowler, Pachuca, Mexico.

Proposed by C. E. Rhodes, Percy E. Holme, E. L. Shera.

Born 1880, Watertown, N. Y. 1886-1898, Public Schools, Watertown, N. Y. 1899-1900, Corcoran Scientific School, Washington, D. C. 1905-07, Shift boss, Cia. Dos Estrellas, El Oro, Mex. 1907-08, Cyanide supt., Guanajuato A. G. mines, Guanajuato, Mex. 1908-12, Mill and cyanide supt., Cia. R. D. M. y Pachuca, Pachuca, Mex. 1912-13, Mill and cyanide supt., Natividad, Oaxaca, Oax. 1913-14, Mill and cyanide supt., Cia Dos Estrellas, El Oro, Mex. 1914-16, Mgr., Cia. Chontalpan, Zacualpan, Mex.

Present position—1917 to date: Gen. Mgr., Cia de Minas La Blanca.

Nelson Franklin, Denver, Colo.

Proposed by Robert M. Keeney, Adolph F. Zang, Jay Lonergan.

Born 1854, Brantford, Ont., Canada. Public schools. 1882-86, Prospecting and mining on own account, Silverton, Colo. 1886-90, Railroad grading contractor, Franklin & Carroll. 1891-92, Chem. lab. and mill work, cyanide process, Gold and Silver Extraction Co., Denver, Colo. 1893, Supt. and chem., San Juan Min. & Mill. Co., Silverton, Colo. 1894, Supt. and chem., Coburn mill, Boulder, Colo. 1895-1900, Mgr. and chem., State Ore Sampling Co., Black Hawk, Colo. 1900-16, Gen'l mgr., The Eagle Ore Co., Victor, Colo., and leasing on own account.

Present position: Mgr., Rare Metals Ore Co., and Black Metals Mines Co., Rollinsville, Colo.

Walter Audley Funk, Idaho Springs, Colo.

Proposed by Harry J. Wolf, Rens E. Schirmer, I. A. Palmer.

Born 1878, Springfield, Ohio. 1897-98, New York Univ. 1898-99, Colorado State Univ. 1899-1900, Teaching school in New Mexico. 1900-03, Colorado School of Mines, E. M. 1903-10, Min. engr. and U. S. mineral surveyor, Central City, Colo. 1910, Knights Island, Alaska, for Ball Min. Co. 1910-11, Civil and min. engr., Idaho Falls, Idaho. 1911, At Central City, Colo.

Present position—1911 to date.: Min. Engr. and U. S. Min. Surveyor.

Charles Horace Glines, Jr., New Brunswick, N. J.

Proposed by H. W. Hardinge, W. N. Best, H. F. E. Gamm.

Born 1880, Bridgeport, Conn. 1902-03, Virginia City School of Mines, Virginia City, Nev. 1901, Vacuero, Rickey Cattle Co., Carson City, Nev. 1902, Miner, Lily Min. Co., Silver City, Nev. 1903, Miner, Silver Hill Min. Co., Silver City, Nev. 1904, Leasing, Silver City, Nev. 1905, Prospecting, Silver Bow and Eden, Nev. 1906, Miner, Montana Tonopah Min. Co.; and leasing. 1907, Foreman, Bullfrog Rush Min. Co. 1908, Custom assaying, Rhyolite, Nev. 1909 and 1910, Leasing, Silver City, Nev. 1911, Assayer, Shallow Croppings Lease, Virginia City, Nev. 1912, Millman, Johnnie Cons. Min. Co., Johnnie, Nev. 1913, Foreman, Conn. Trap Rock Co., Wallingford, Conn. 1914-16, Constr. engr.; supt. 1917, Gen'l supt., U. S. Nickel Co.

Present position: Personal.

Frank Benjamin Goodman, Hurley, Wis.

Proposed by Duncan MacVichie, E. W. Hopkins, O. C. Davidson.

Born 1881, Sands, Marquette Co., Mich. 1899, Grad., High School, Ishpeming, Mich. 1900, Grad. Detroit Business Univ. 1904, Michigan College of Mines,

Houghton, Mich., B. S., E. M. 1904, Laborer and asst. engr., smelter, Bingham Cons. Min. & Smelt. Co., Bingham Canyon, Utah. 1904-06, Engr., Mexico Cons. Min. & Smelt. Co., Guanacevi, Dgo., Mexico. 1906-07, Asst. engr., Colorado Fuel & Iron Co., Colo. 1907-09, Engr., Ringham Cons. Min. & Smelt. Co. & Ohio Copper Co., Lark, Utah. 1909, Supt., Ohio Copper Co., Lark, Utah. 1909-13, Asst. mgr., The Montreal Min. Co., Hurley, Wis.

Present position—1913 to date: Supt., The Montreal Min. Co.

George Leroy Green, Oklahoma City, Okla.

Proposed by H. B. Goodrich, Alfred G. Heggem, James H. Gardner.

Born 1890, Keithsburg, Ill. 1917, Grad., Univ. of Oklahoma, A. B., Geol. and Civil Engr. Until 1916, a farmer at home. 1916-17, Geological work for private parties. 1917, Geol., Dundee Petroleum Co., Tulsa, Okla.

Present position—1917 to date: Geol., Gladstone Oil and Refining Co., Oklahoma City.

Edward Franklin Guidinger, Bartlesville, Okla.

Proposed by Walter M. Small, Earl Oliver, James H. Gardner, F. Julius Fohs.

Born 1886, Schuyler, Neb. 1904, Grad., High School, Schuyler, Neb. 1909, Univ. of Nebraska, Electrical Engr., B. S. 1909-12, Varied employment, engr. work, engr. sales, specialty sales, etc. 1912-17, Engr., geol., ch. engr. and supt., Gasoline Dept., Wolverine Oil Co., Tulsa, Okla.

Present position—1917 to date: Gen. Supt., Mid-Continent Gasoline Co.

Walter E. Hadsell, Ajo, Ariz.

Proposed by C. A. Hansen, Ben H. Cody, Henry A. Tobelmann.

Born 1880, Lima, Ohio. 1898-1904, Univ. of Arizona. 1905-06, Cyanide shift boss, Tombstone Cons. Mines Co., Tombstone, Ariz. 1906-07, Cyanide shift boss and refinery foreman, El Oro Min. & Refin. Co., El Oro, Mex. 1907-11, Refinery foreman, Mexico Mines of El Oro, El Oro, Mex. 1911-15, Mercantile business for myself, Vera Cruz, Mexico. 1916-17, Refinery foreman, New York & Honduras Rosario Min. Co., San Juancito, Honduras, C. A.

Present position: Assayer and Chem., New Cornelia Copper Co.

Earl Emmet Hunner, Duluth, Minn.

Proposed by W. G. Swart, D. E. Woodbridge, William Wearne.

Born 1876, Eau Claire, Wis. 1894-1900, Univ. of Wisconsin, B. S. C. E. 1907, Univ. of Wisconsin, C. E. 1898-99 (Summers), Traverseman, U. S. Geol. Survey. 1898-99, Mucker and miner, Republic, Wash. 1899-1900, Draftsman, Great Northern Ry., Spokane, Wash. 1900-01 (Summers), Asst. topogr., U. S. Geol. Survey. 1900-01, Office engr., Great Northern Ry., Spokane, Wash. 1901-02, Min. engr., Republic, Wash. 1902, Location survey, Northern Pacific Ry., Toppenish to Lyle, Wash. Construction foreman, Sullivan Smelt., Marysville, B. C. 1903-05, Min. engr., Oliver Iron Min. Co., Chisholm and Buhl, Minn. 1905-09, Chief engr., Oliver Iron Min. Co., Hibbing and Chisholm districts, Minn. 1909-12, Asst. gen. min. engr., Oliver Iron Min. Co., Duluth, Minn. 1912-14, Chief engr., Great Northern ore properties, Duluth, Minn. 1917 (June), Mgr., Iron Mines, M. A. Hanna & Co.

Present position—1914 to date: Gen. Supt., Great Northern iron ore properties.

John Vincent Kelly, Pachuca, Mexico.

Proposed by C. E. Rhodes, Percy E. Holme, E. L. Shera.

Born 1882, Buffalo, N. Y. Attended public schools, Buffalo, N. Y. 1905, General Science, Harvard Univ., B. S. 1906, Lawrence Scientific School, Harvard Univ., B. S. in Min. 1906-07, Asst. engr., Guantanamo Exploration Co. of N. Y., work in Cuba. 1907-08, Asst. engr., Imboden Coal & Coke Co., Imboden, Va. 1908-09, Asst. engr., construction, Tintic Smelt. Co., Tintic, Utah. 1909-11, Millman, McGill Concentrator, Ely, Nev.; miner, Bisbee, Ariz.; shift boss, Shannon mines, Metcalf, Ariz. 1911-13, Mine shift boss, Esperanza Min. Co., El Oro, Mexico; mine foreman, Maxapil Copper Co., Zacatecus, Mexico. 1913-14, Mine supt., El Favor Min. Co., Jalisco, Mex. 1914-16, Exploration work, Nicaragua and Honduras, C. A.; mine shift boss, Burro Mountain Copper Co., Tyrone, N. M.

Present position—1916 to date: Gen. Supt., Cia La Blanca y Anexas, S. A.

Dana Winston Leeke, Nantei, Tul Mi Chung Mine, Korea.

Proposed by A. R. Weigall, W. W. Barnett, A. H. Collbran.

Born 1886, Yainax, Ore. 1904, Grad., High School, Ontario, Cal. 1908, Pomona

College, Claremont, Cal., B. S. 1910, Colorado School of Mines, Golden, Colo., E. M. 1905-08 (Summers), Inside wiring, meter calibration, chief repairman, Ontario Power & Light Co., Ontario, Cal. 1910-11, Concentration foreman, The Magna Copper Plant, Utah Copper Co., Garfield, Utah. 1912-16, Mill shift boss, Suan mine, Seoul Min. Co., Holkol, Korea. 1916-17, Assayer and surveyor, Seoul Min. Co., Korea.

Present position: Asst. Supt., Surveying and Ore Estimation Dept., Seoul Min. Co.

Edward A. Manderfield, Monterey, Mexico.

Proposed by E. F. Salisbury, Henry Bornhoft, C. Q. Schlereth.

Born 1887, Houghton, Mich. 1892-1902, Adams Township High School, Atlantic, Mich. 1902-04, Student, St. Francis Seminary, Milwaukee, Wis. 1907, Grad., Rockland High School, Rockland, Mich. 1911, Grad., Michigan College of Mines, Houghton, Mich., B. S., E. M. 1911-12, Engr., Oliver Iron Min. Co., Hibbing, Minn. 1912-13, Engr., American Smelt. & Refin. Co., Anganguco, Mich., Mex. 1913, Engr. U. S. Smelt & Refin. Co., Real Del Monte, Mexico. 1913-14, Ch. engr., Bonanza mines, Canadian Agency Ltd., Nicaragua, C. A. 1915-16, Ch. engr., Ojuela mines, Cia. Minera de Peñoles, Mapimi, Durango, Mexico. 1916-17, Ch. engr., Cia. de Minerales y Metales S. A., Monterey Div., Monterey, N. L., Mexico.

Present position—1917 to date: Supt., Cerralvo Mines, Cia. de Minerales y Metales, S. A.

Henry Wadsworth Longfellow Maxwell, Denver, Colo.

Proposed by V. A. Hart, O. M. Kuchs, Ralph Nichols.

Born 1889, Nashville, Tenn. 1904, Grad., grammar school, Nashville, Tenn. 1905-07, Three terms night school, mech. engr., Vanderbilt Univ. 1907-18, Practical experience and home study. 1905-07, Serving apprenticeship as machinist, Nashville Machine Co., Nashville, Tenn. 1907-09, Machinist, American Tool Co. and Nordberg Mfg. Co. 1909-12, Manufacturing and installing mining machinery, John A. Traylor Machinery Co. and F. M. Davis Iron Works, Denver, Colo. 1912-14, Mechanical expert, installing and operating machine, Salt Lake Engr. Co. 1914-16, Expert on Marcy mill, Mine & Smelter Supply Co. 1916-18, Mechanical and operating expert on Marcy mill.

Present position: Expert Marcy Mill Operator, Mine & Smelter Supply Co.

Jose Maria Mejia, Berkeley, Cal.

Proposed by H. W. Turner, S. E. Bretherton, H. L. Huston.

Born 1894, Medellin, Colombia. 1915, Grad., National School of Mines, Colombia, S. A., M. E. 1916, Surveyor and cyanide man, Belgian Co., "Mines de la Colombie," Colombia, S. A. 1918, Cyanide man, Melones Mining Co., Cal.

Present position: Flotation Expert, Quail Hill Min. Co., Milton, Cal.

Richard Charles Morrison, Vanadium, Colo.

Proposed by Robert Sterling, Harold Boericke, Augustus MacDonald.

Born 1877, Boulder, Colo. 1883-91, Public schools, Boulder, Colo. 1892-95, State Preparatory School, Boulder, Colo. 1896-97, State Univ., Boulder, Colo., specialized in chemistry. 1897-98, Chem., assayer, Delano Min. & Mill. Co., Boulder, Colo. 1898-99, Chem., assayer, Gilt Edge Min. & Mill. Co., Rapid City, So. Dak. 1899-1900, Chem., assayer, Atlas Min. & Mill. Co., Boulder, Colo. 1901-02, Foreman, Chlorination Dept., Union Gold Extraction Co., Florence, Colo. 1903-05, Lead burner, mill foreman, Portland Gold Min. Co., Colorado Springs, Colo. 1905-06, Chem., supt., Myrtle Min. & Mill. Co., Ward, Colo. 1906-10, Melter, melter foreman, United States Mint, Denver, Colo. 1911-18, Foreman, mill supt., Primos Chemical Co., Vanadium, Colo.

Present position: Gen'l Supt., Primos Chemical Co.

Pierre Muller, Pachuca, Mexico.

Proposed by C. E. Rhodes, Percy E. Holme, E. L. Shera.

Born 1868, Douai, France. 1891, Ecole des Mines du Hainaut, Belgium, M. E. 1890-95, Engr., Cia. Charbonnages Belges, Belgium. 1895-1900, Ch. engr., The Metelin Bank, Turkey. 1900-02, Gen'l mgr., Mines of Cistierra, Spain. 1902-10, Gen'l mgr., Mines of Espina, Spain. 1910-13, Gen'l mgr., Mines of Alaba, Spain. 1914-16, Geol., Monterey Cia., Mexico. 1916-18, Engr., Blanca Mine, Mexico.

Present position: Ch. Engr., Blanca Mine.

Merle Louis Nebel, Urbana, Ill.

Proposed by H. H. Stoek, E. A. Holbrook, Gilbert H. Cody.

Born 1892, Clinton, Ill. 1897-1909, Grade and high schools, Clinton, Ill. 1909-13, Univ. of Illinois, B. S. 1913-15, Engr. Experiment Station, Fellow in Min. Engr., Univ. of Illinois; 1915, M. S. in Mining. 1915-17, Fellow in Geology, Univ. of Illinois; 1917, Ph. D. in Geology. 1912 (Summer), Field asst., Illinois State Geological Survey. 1913 (Summer), Miner, Calumet & Arizona Min. Co., Bisbee, Ariz. 1914 (Summer), Office asst., Illinois State Geological Survey. 1915-16 (Summers), Geol., exploration for oil and gas in Mid-Continent Field, Denman Bros., Sedan, Kans.

Present position—1917 to date: Geol. in charge of oil studies, Illinois State Geological Survey.

David Franklin Newman, Elkton, Va.

Proposed by F. Lynwood Garrison, H. F. LeFevre, Thomas L. Watson.

Born 1883, Lakewood, N. J. 1889-99, Public schools, Lakewood, N. J. 1907, Mt. Hermon Boys' School, Mt. Hermon, Mass. 1908, Keuka College, Keuka Park, N. Y. 1908-09, Grove City College, Grove City, Pa. 1910-11, School of Mines, Oregon Agricultural College, Corvallis, Ore. 1899-02, Clerk, head clerk and buyer, A. S. Larrabee, General Merchandise, Lakewood, N. J. 1903, Mucker and trammer, "Gold Coin" gold mine, Victor, Colo.; mucker, trammer, steel nipper, powder monkey, "Independence" gold mine, Victor, Colo. 1904, Helper construction, unwatering and sampling mine, "Black Queen" silver mine, Crystal, Colo.; machine and hand drilling, timbering, ore sorting, mucking and tramping for Mr. Drum, "Ajax" gold mine, Victor, Colo. 1905, Asst. in unwatering shaft, Prospect Shaft, Victor, Colo.; general underground work, "Dillon" gold mine, Victor, Colo. 1905-06, Asst. to mgr., Northwest Mines Co., Grants Pass, Ore. 1906-07, Shift foreman, Esperanza mill, El Oro, Mex.; shift boss, underground, El Oro gold and silver mine, El Oro, Mex. 1911, Helper and diver on gold dredge, P. H. Holdsworth, Galice, Ore.; surveying, W. F. Raithel, Grants Pass, Ore. 1912-16, Mgr., proprietor, general mercantile, Galice, Ore. and Latrobe, Pa.

Present position—1916 to present: Supt. and Gen'l Supt., U. S. Manganese Corporation, Elkton, Va.

Samuel D. Nicholson, Denver, Colo.

Proposed by Richard A. Parker, Fred H. Bostwick, S. A. Ionides, Frank Bulkley.

Born 1859, Prince Edward Island, Canada. Attended public school, Bay City, Mich. 1881-83, With Robinson Min. Co. 1883-85, Richtenberg coal mines, Las Animas Co., Colo. 1885-87, Foreman, Col. Sellers Min. Co., Leadville, Colo. 1887-92, Supt., A. Y. & Minnie Co.

Present position—1892 to date: Pres. and Gen'l Mgr., Western Min. Co., Leadville, Colo.

Daniel Webster Ohern, Oklahoma City, Okla.

Proposed by Irving Perrine, C. N. Gould, C. W. Shannon.

Born 1870, Galesburg, Ill. 1898, Drake Univ., A. B. 1899, West Virginia Univ., A. M. 1907, Johns Hopkins Univ., Ph. D. (Geology). 1904-07, Asst. Geol. Maryland and U. S. Geol. Surveys. 1907-11, Asst. Geol., Oklahoma and U. S. Geol. Surveys. 1911-13, Director, Oklahoma Geol. Survey.

Present position—1913 to date: Chief Geol., Fortuna Oil Co.

G. C. Potter, Tulsa, Okla.

Proposed by E. W. McCrary, H. Harper McKee, Noah C. Adams.

Born 1892, Meade, Kans. 1914, Arkansas Univ., B. C. E. 1912-14, Miller Engineering Co., Little Rock, Ark.

Present position—1915 to date: Geol., C. N. Gillespie.

Alfred Schwarz, Joplin, Mo.

Proposed by J. N. Houser, Howard I. Young, H. A. Buehler.

Born 1878, Coburg, Germany. Casimirianum, Coburg Technical High School, Charlottenburg. 1900, Engaged in electrolytic metal refining. 1903, Ore testing, especially flotation. First patent, Aug., 1903. Series of patents following this, including 807501, Sulphide Filming Process now practised at Magna Copper Co. and other plants. Recent patents also pertaining to flotation.

Present position: Consulting engr. practice, principally flotation and ore treatment.

Herman L. Snyder, Ajo, Ariz.

Proposed by Henry A. Tobelmann, Ben H. Cody, C. A. Hansen.

Born 1877, Silverton, Colo., 1896. Grad., Denver High School. 1897-99, International Smelter, El Paso, Tex. 1900-02, El Paso Smelter, El Paso, Tex. 1903, Gen. foreman, Federal Copper Co., El Paso, Tex. 1904, Smelt. supt., Chinitte Min. & Smelt. Co., Shafter, Tex. 1905-06, Smelt supt., Encinillas Mines, Ltd. 1907-13, Supt., Rio Tinto Copper Co., Tarrasas, Mex. 1914-16, Roaster foreman, C. & A. Smelter, Douglas, Ariz.

Present position: Supt., Roaster and Gas Plant, New Cornelia Copper Co.

Harold Andrew Steven, Worthington, Ont., Canada.

Proposed by R. N. Palmer, C. V. Corless, O. Hall.

Born 1885, Perth Co., Ontario. 1910-17, Kingston School of Mining (Affiliated with Queen's Univ.), B. S. 1905-10, Bookkeeper and cashier, J. & J. Taylor, Toronto, Ont. 1912-13, In office and underground, Lake Superior Corporation. 1913-16, Surveyor and engr., Worthington mine, Mond Nickel Co., Ltd.

Present position—1917 to date: Underground Foreman, Worthington Mine.

L. W. Storm, Juneau, Alaska.

Proposed by G. T. Jackson, E. V. Daveler, P. R. Bradley.

Born 1879, Rochester, Pa. 1887-94, Common schools, Denver, Colo. 1894-97, West Denver High School. 1898-1902, Colorado School of Mines. 1902-03, Asst. geol.; 1903-07, Asst. engr., Utah Fuel Co. 1906-07, Engr., Dawson Fuel Co., Dawson, N. M. 1907-14, Min. Engr., U. S. Min. Survey, Valdez, Alaska.

Present position—1914 to date: Geol., Alaska Gastineau Min. Co., Perseverance, Alaska.

Hideji Taketa, Shimotsuko, Japan.

Proposed by J. S. Shedden, W. L. Saunders, Jintaro Kojima, Nosaku Asano, Masayuki Otagawa.

Born 1885, Akitaken, Japan. Grad., Engr. Branch, Tokyo Imperial Univ., Tokyo, Japan. 1910, Grad., Imperial Univ., Tokyo, Japan. 1910-11, Designed machinery, Engr. Dept., Ashio mines. 1912-13, Training at Allis-Chalmers plant, Milwaukee, Wis. 1913, Training at Ingersoll-Rand plant, Easton, Pa. 1913-14, Inspecting and visiting manufacturers of mining machinery and leading mines and smelteries of the U. S. 1914-16, Supt. mech. dept., cons. engr., designing dept., supt. of designing and construction, new smelters, Ashio mines. 1916-18, In United States purchasing machinery for the Furukawa Min. Co.

Present position: Ch. Mech. Engr., Ashio Mines.

John H. White, Climax, Colo.

Proposed by Dennis F. Haley, M. W. Hayward, H. L. Brown, O. R. Whitaker.

Born 1876, England. Attended public and high schools of Penzance, Cornwall, England. Supt., Creede Triune Mines Co., Creede, Colo. Supt., Boston mine, Kokomo, Colo., for John B. Carter Construction Co. of New York. Supt., London Mines Co., Tolland, Colo. Supt., Tonopah Belmont property, Emma mine, Dunton, Colo.

Present position: Mgr., Climax Branch, American Metal Co., Ltd.

Arthur Worsdell, Kendall, Mont.

Proposed by George T. McGee, J. H. McCormick, C. W. Goodale.

Born 1880, Vermont, Ill. 1898-1900, Univ. of Illinois, C. E. 1900-03, in father's grocery store, Vermont, Ill. 1903-04, Laborer and cyanide man, Chicago-Montana Gold Min. Co., Gilt Edge, Mont. 1904, Gold Reef Min. Co., Gilt Edge, Mont. 1905-06, Cyanide man, Park-New Era mines, Mason, Mont. 1907-10, Farming. 1910-12, Cyanide man, McGunness Lease, Maiden, Mont.

Present position—1913 to date: Mill Foreman, Barnes King Development Co.

Nobuo Yamamoto, Tadakuma, Japan.

Proposed by Kenroku Ide, Tatsuro Otagawa, Keijiro Nakamura, R. W. Raymond.

Born 1880, Hikone, Japan. 1907, Grad., Mechanical Dept., Kyoto Imperial Univ., Kyoto, Japan.

Present position—1907 to date: Gen'l Mgr., Tadakuma Colliery, Sumitomo-Wakamatsu Coal Dept.

Associates

Edward Alexander, El Paso, Tex.

Proposed by P. A. Mosman, Judd Stewart, H. A. Prosser.

Born 1884, New York City. 1898, Grammar schools, New York City. 1903-13, High school, New York City. 1913-14, School of Commerce, Accounts and Finance, New York Univ. 1915-16, Post-graduate course, Broaker School of Accountancy. 1903-04, General business experience. 1904-06, Asst. to gen'l mgr., V. J. Hedden & Sons, contr. and builders, New York. 1906-07, Field clerk, North River div. Pennsylvania R. R. tunnels. 1907-09, Traveling throughout the U. S., particularly Pacific Coast, British Columbia and northwestern Alaska (Seward Peninsula), where I undertook some prospecting work in own interest. 1909-12, Clerk, auditing dept. 1912-16, Chief clerk, American Smelt. & Refin. Co., New York. 1916, Cashier, Nevada Cons. Copper Co., Nevada Northern R. R. Co., New York. 1916-17, Sec. to Mr. Karl Eilers, Vice-pres. of American Smelt. & Refin. Co.

Present position—1917 to date: Asst. to Chief Accountant, Mexican Dept., American Smelt. & Refin. Co.

William Holzhauer, Cleveland, Ohio.

Proposed by Charles H. Fulton, Frank R. VanHorn, C. B. Murray.

Born 1895, Amherst, Ohio. 1909-13, Amherst High School. 1913-14, Oberlin College. 1914-18, Case School of Applied Science. B. S. in Metallurgy.

Present position: Student of Ordnance for Engr. of Tests, Carnegie Institute of Technology, Pittsburgh, Pa.

Stephen Smilie Jones, Kingman, Ariz.

Proposed by George W. Mark, D. E. Blake, R. C. Jacobson.

Born 1872, Troy, Ala. 1894, Grad., Ohio State Univ., E. M. 1894, Electrician, Gold Bluff mine, Sierra Co., Cal. 1895, Assayer, South Eureka mine, Amador Co., Cal. 1896, Assayer, private practice. 1897-1901, Supt., Empire Gold Min. & Mill. Co., Prescott, Ariz. 1902, Mine supt., Esperanza mine, Cedros Island, Mexico. 1903-05, Supt., Arondo Gold Mines Co., Ingo Co., Cal. 1906, Private practice. 1907-16, Gen'l mgr., Love Reed Gold Mines Co., Oatman, Ariz.

Present position—1917 to date: President, Argo Mines Co., and Loyal Min. Co.

Anthony Joseph Lanza, Pittsburgh, Pa.

Proposed by D. J. Parker, H. I. Young, Charles T. Orr, C. Edwin Nighman.

Born 1884, New York, N. Y. 1906, George Washington Univ., Washington, D. C., M. D. 1907-18, U. S. Public Health Service, four years coöperative service, U. S. Bureau of Mines, investigating occupational diseases of miners, and hygienic conditions underground.

Present position: P. A. Surgeon, U. S. Public Health Service, in charge of investigations of industrial hygiene, U. S. Public Health Service.

Loyal Ambrose Shoudy, Bethlehem, Pa.

Proposed by Thomas T. Read, C. A. Buck, Francis P. Sinn, W. L. Cumings.

Born 1882, Ellensburg, Wash. 1900-04, Univ. of Washington, A. B. 1904-05, Univ. of Washington, post grad., chemistry. 1905-09, Univ. of Pennsylvania, M. D. 1909-12, German Hospital, Philadelphia, Pa. 1912-13, Mary Drexel Hospital, Philadelphia, Pa.

Present position: Chief Surgeon, Bethlehem Steel Co.

Kosaku Ueno, Tokyo, Japan.

Proposed by Tadashi Inouye, H. Naito, D. Matsuzawa.

Born 1887, Fukuoka, Japan. 1914, Grad., College of Engineering, Imperial Univ., Tokyo, Japan.

Present position—1914 to date: Engr., Producing Dept., Nippon Oil Co., Ltd.

Samuel Webster Wells, Tulsa, Okla.

Proposed by R. A. Conkling, F. B. Plummer, C. A. Hammill, John R. Suman.

Born 1892, Madison, Wis. 1911-15, Univ. of Chicago, S. B. 1915-16, Engrg. Dept., Kennicott Co., Chicago, Ill.

Present position—1916 to date: Geol., Roxana Petroleum Co.

Junior Associates

Juan L. Carrasco-Calvo, Ithaca, N. Y.

Proposed by H. Ries, R. E. Somers, L. P. Teas.

Born 1894, Chile, S. A. 1914, State University in Santiago, Chile, Bachelor in Humanities, Bachelor in Mathematics.

Present position: Mining Student, Cornell University.

Ralph Lewis Dowdell, St. Paul, Minn.

Proposed by W. R. Appleby, Peter Christiansen, John F. Murphy.

Born 1896, St. Paul, Minn. 1909, Tilden Grammar School. 1913, Mechanic Arts High School.

Present position: Student, Univ. of Minnesota, School of Mines.

John Francis Otto, Hastings, Pa.

Proposed by Robert M. Black, Henry Leighton, Roswell H. Johnson.

Born 1887, Hastings, Pa. Worked five years in the various mines of Cambria County.

Present position: Senior, Univ. of Pittsburgh, School of Mines.

Harry Meeker Rockwell, Houghton, Mich.

Proposed by F. W. Sperr, Albert J. Houle, W. E. Hopper.

Born 1890, Crown Point, Ind. 1909, Grad., High School. 1909-10, Student, Michigan College of Mines. 1911-12, Student, Michigan College of Mines. 1915, Student, Michigan College of Mines. 1910-11, Colonial mine, Cobalt, Ont., Canada. 1912-14, City Engineer's office, Flint, Mich. 1916-18, International Smelter, Tooele, Utah.

Present position: Student, Michigan College of Mines.

Harry W. Strand, Marine Mills, Minn.

Proposed by John F. Murphy, W. R. Appleby, Peter Christiansen.

Born 1891, Marine Mills, Minn. 1898-05, Marine graded schools. 1907-11, Minnesota College.

Present position—1913 to date: Student, School of Mines, Univ. of Minnesota.

Ching Fang Tu, Houghton, Mich.

Proposed by Albert J. Houle, J. B. Cunningham, W. E. Hopper.

Born 1891, Kirin, China. 1910, Grad., Kirin High School, China. 1913, Tobin High School, Japan. 1914, University of Illinois.

Present position—1915 to date: Student, Michigan College of Mines.

Change of Status—Junior Associate to Member

Anthony Wayne Caruthers, Nanticoke, Pa.

Proposed by Robert A. Quin, E. Ludlow, J. S. Warriner, W. G. Whildin, William W. Inglis.

Born 1891, Irwin, Pa. 1891-05, Irwin Public Schools. 1905-08, High school, Irwin, Pa. 1908-09, Washington and Jefferson College. 1909-13, Columbia Univ., School of Mines, N. Y., E. M. 1909 (Summer), Engr. Corps. 1909-13 (Summers), Working at Columbia School of Mines. 1913, Practical work, Woodward Colliery, D. L. & W. R. R. Co. 1913-15, With R. V. Norris, Cons. Engr., on valuation of Temple Iron Co. and Susquehanna Coal Co. properties. 1915-16, Asst. supt., Coaldale Colliery, Lehigh Coal & Navigation Co., Coaldale, Pa. 1916-17, General and special engr., Coal Min. Dept., D. L. & W. R. R. Co.

Present position: Colliery Supt., Bliss Colliery, D. L. & W. R. R. Co.

Frank H. Madson, Bessemer, Mich.

Proposed by A. N. Winchell, W. J. Mead, C. K. Leith.

Born 1890, Racine, Wis. 1908-13, Univ. of Wisconsin, B. S. in Min. Engr. 1911-12, Student, Montana State School of Mines, Butte, Mont. 1914, Min. Engr., Oliver Iron Min. Co., Virginia, Minn. 1915-17, Min. Engr., Newport Min. Co., Bessemer, Mich. 1911-12, Miner, etc., Anaconda Copper Min. Co., Butte, Mont.

Present position—1917 to date: Min. Engr., The McKinney Steel Co.

CHANGE OF ADDRESS OF MEMBERS

The following changes of address of members have been received at the Secretary's office during the period Apr. 10, 1918 to May 10, 1918.

This list together with the list published in Bulletin Nos. 133 to 137, January to May, 1918, and the foregoing list of new members, therefore, supplements the annual list of members corrected to Jan. 1, 1918 and brings it up to the date of May 10, 1918.

- ALFORD, NEWELL GILDER.....St. Bernard Min. Co., Earlington, Ky.
 ANDERSON, ARTHUR P.....Leasee, R. F. D. 2, Phoenix, Ariz.
 AUBEL, V. W.....20 Smithfield St., New Castle, Pa.
 AUSTIN, L. S.....The Knickerbocker Apts., 821 So. Hope St., Los Angeles, Cal.
 BACON, RAYMOND F.....Lieutenant-Colonel, Chemical Service Section, N. A.,
 A. E. F., France.
 BAIN, H. FOSTER.....Care U. S. Bureau of Mines, Washington, D. C.
 BALLENGER, ADOLF G.....1st. Lieut., Ordnance Dept., U. S. Army,
 P. O. 717, A. E. F., France.
 BANDY, PERCY J.....Apartado 533, Mexico, D. F.
 BARKER, E. E., Supt. of Mines, Cerro de Pasco Copper Corp., Cerro de Pasco, Peru.
 BASSETT, ARTHUR F.....Engr., Hyatt Roller Bearing Co., Metropolitan Tower,
 New York, N. Y.
 BATESON, C. E. W.....Hill Top Farm, Kingston Pike, Knoxville, Tenn.
 BECK, HOWARD A.....2225 Grove St., Denver, Colo.
 BECKWITH, H. T., Capt., Engineers R. C., Headquarters Co., 312th
 Engineers, Camp Pike, Ark.
 BEDWORTH, H. A.....Scovill Mfg. Co., Waterbury, Conn.
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NECROLOGY

The deaths of the following members were reported to the Secretary's office during April 10, 1918, to May 10, 1918.

Date of Election.	Name.	Date of Death.
1895	Elliott, Arthur H.....	1918.
1902	Nau, John B.....	Apr. 3, 1918.
1903	Nichol, William.....	May, 1917.
1914.	Reeser, Harry Clayton.....	Mar. 30, 1918.

BIOGRAPHICAL NOTICES

JOHN R. LUCAS

John R. Lucas was born Apr. 15, 1866, at St. Louis, Mo. From his 19th year until his death on his 51st birthday anniversary, he was engaged in the mining industry, in which, however, he made his beginning and achieved his progress after a somewhat unusual fashion. Presumably without previous training as a mining engineer, he became in April, 1885, and remained until the end of 1892, bookkeeper of the Granite Metal Mining Co. at its St. Louis office. Then for a year he served as bookkeeper of the same company at its mine in Montana. This official of a mining company is at the very heart of its operations; and if he possesses ambition and intelligence, may learn the business thoroughly. It is not surprising, therefore, that Mr. Lucas, being that kind of man, assumed, in 1894, a position with the Hope Mining Co., another St. Louis corporation operating in Montana, which he retained for eight years, serving not only in the office, but becoming also successively mill foreman and assayer.

This varied practical experience prepared him for important administrative functions. From April, 1902, he was for many years the business agent of the Goodhope Mining Co. In 1903, he became also the assistant superintendent of the Granite Bi-metallic Consolidated Mining Co., and subsequently its superintendent—a position which he retained until his health failed at the end of 1916. In addition to the other Granite Bi-metallic properties, he had charge of the sapphire mines in the west fork of Rock Creek, Mont., the Basin Gulch placer mines, the claims of the former Hope Co., etc., all of which he managed with skill, integrity and recognized business ability.

This creditable career, almost wholly achieved in one region—Granite County, Montana—naturally made him an influential citizen, and brought him a host of friends. He was a popular employer and a congenial companion. In May, 1906, he was elected to membership in this Institute. His death, which occurred after several months' illness, at Long Beach, Cal., on Apr. 15, 1917, was widely and sincerely mourned. He is survived by his son, John J. Lucas, now in the employ of the Anaconda Copper Mining Co.

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REQUIREMENTS FOR MEMBERSHIP

Extract From Constitution

ARTICLE II

MEMBERS

SEC. 1. The membership of the Institute shall comprise four classes, namely: 1. Members; 2. Honorary Members; 3. Associates; 4. Junior Associates.

All members shall be equally entitled to the privileges of membership, excepting that Honorary Members, Junior Associates, and Members and Associates whose residences shall be outside of the United States, Mexico, and Canada shall not be entitled to vote. Members and Associates residing within the United States of America, Mexico, and Canada, and not in arrears for dues, shall be entitled to vote in person at the meetings of the Institute, or, as hereinafter provided for, by letter ballot.

SEC. 2. MEMBERS shall comprise all those persons who on the third Monday of February, 1918, were members of the Institute, and in addition thereto, all those, thereafter elected or transferred into the class of Members.

MEMBERS must be at least 27 years of age and must have had at least six years, employment in the practice of engineering, mining, geology, metallurgy or chemistry, during at least three years of which they must have held positions of responsibility in one or more of these fields.

Graduation from the scientific course of a college, approved by the Committee on Membership, shall be considered equivalent to two years' employment, as required in the previous sentence.

Employment as a teacher of engineering, mining, geology, metallurgy or chemistry, if in direct charge, may be considered a position of responsibility as specified in the second paragraph.

Persons employed in research or any scientific literary work or in teaching in the scientific departments of colleges, approved by the Committee on Membership, who at the same time are engaged in consulting or in the active practice of mining, geology, or metallurgy, shall be entitled to consider the time so spent in active practice as equivalent to an equal length of time of employment in positions of responsibility, provided the work done or the positions held seem to the Committee on Membership to warrant the equivalency.

The requirement of three years' employment in positions of responsibility may be waived by the Committee on Membership in the case of persons who have done notable original work in mining, geology, or metallurgy, or have won distinction by research or investigations in one or more of these subjects. By investigation or research is understood laboratory experimentation as distinct from investigations in literature or compilations of the work of others.

ASSOCIATES shall be those, who, in the opinion of the Committee on Membership and the Board of Directors, are suitable for such election or transfer by reason of their interest in or connection with mining, geology, metallurgy, or chemistry.

JUNIOR ASSOCIATES shall comprise all students in good standing in engineering schools, who have not taken their degrees and are nominated by at least three members, two of whom must be their instructors. A Junior Associate may remain such not longer than five years after leaving the engineering school, at the end of which period his qualifications to become a Member or Associate must be passed upon by the Committee on Membership. If elected he shall pay at that time the entrance fee and dues of a Member or Associate.

In case there is any question as to the classification of a candidate the Committee on Membership may require from him any evidence he desires to present and the decision of the Committee as to the proper status shall be final.

Every candidate for election as a Member, Associate, or Junior Associate must be proposed for election by at least three Members or Associates, must be approved by the Committee on Membership, as prescribed in the By-Laws, and must be elected by the Board of Directors.

DISCUSSION OF THIS PAPER IS INVITED. It should preferably be presented in person at the Colorado meeting, September, 1918, when an abstract of the paper will be read. If this is impossible, then discussion in writing may be sent to the Editor, American Institute of Mining Engineers, 39 West 39th Street, New York, N. Y., for presentation by the Secretary or other representative of its author. Unless special arrangement is made, the discussion of this paper will close Oct. 1, 1918. Any discussion offered thereafter should preferably be in the form of a new paper.

The Metallography of Tungsten

BY ZAY JEFFRIES,* B. S., MET. E., CLEVELAND, OHIO

(Colorado Meeting, September, 1918)

TUNGSTEN has the highest melting point of all the known metals, namely $3350^{\circ}\text{C}.$; it is one of the hardest of the metals; it has the highest equiaxing or recrystallization temperature after strain hardening, of any pure metal known. It is particularly distinguished because, when composed of small equiaxed grains, it is extremely brittle and fragile at room temperature, and when possessing a fibrous structure it may be ductile and pliable at room temperature. The common ductile metals act in exactly the opposite manner in this respect.

The present paper will include a brief note regarding the manufacture of wrought and ductile tungsten. The metallography of wrought and ductile tungsten in the various stages of manufacture will be considered more or less in detail. The general relationships between the properties of tungsten and other metals will also be considered.

A discussion will be given explaining why fibrous tungsten is ductile at room temperature, even though past experience with other metals would indicate that it should be brittle. Finally, a brief note regarding some new fundamental metallographic propositions relating to all metals will be given.

MANUFACTURE OF WROUGHT AND DUCTILE TUNGSTEN

Up to about 10 years ago, it had not been possible to mechanically work tungsten. About the year 1908, Dr. William D. Coolidge, of the General Electric Co., produced ductile tungsten from what was then supposed to be an inherently brittle metal and which, in fact, was inherently brittle in its normal state, that is, when composed of equiaxed grains. Since that time many products, chief among which are the filaments for electric incandescent lamps, have been made from wrought and ductile tungsten.

Tungsten is produced chiefly from the minerals wolframite, and sheelite.¹⁻³ The ores may be refined in many ways. For example, the ore may be fused with alkali carbonates and the fusion dissolved in water; sodium tungstate is formed, which is soluble in water. This

* Director of Research, Aluminum Castings Co.

¹⁻³References are to bibliography at end of paper.

may be changed to tungstic oxide WO_3 , by the addition of an acid to the sodium tungstate liquor. WO_3 , a yellow precipitate, is separated by filtering. The tungsten oxide may then be purified to any desired degree by dissolving it in ammonia and then reprecipitating by the addition of acid, followed by filtering and washing.

For the manufacture of most of the wrought tungsten products, the tungsten oxide is treated as follows: after drying, sufficient thorium nitrate solution is added to make 0.75 per cent. thoria (ThO_2) in the oxide. The tungsten oxide is made into a batter with the thorium nitrate solution, additional water being added if necessary, after which it is thoroughly mixed. The mixture is then dried and placed in either a fire-clay or a silica crucible and heated to about 1100°C . for a period usually in excess of 1 hr. This is called the firing operation, and it has for its purpose the agglomerating of the extremely fine particles of tungsten oxide into larger, or coarser-grained particles. When the firing is done in a fire-clay crucible, some of the crucible material is dissolved by the oxide, and produces a beneficial effect when the metal is to be used for incandescent lamp filaments.

The fired oxide is then reduced by hydrogen to tungsten metal powder, at a temperature in the neighborhood of 1000°C . The tungsten powder thus produced is relatively coarse grained when compared to the tungsten powder from which the sintered tungsten filaments were made before the advent of drawn tungsten wire.

The tungsten powder is pressed dry, into any desirable shape or size. A common size and shape consists of a rod about 16 in. (40 cm.) long having a cross-section about $\frac{3}{8}$ in. (9.5 mm.) square. The pressure on such a rod must be applied from the side of the mold and not from the end, else the resulting tungsten ingot will not be workable. The pressed tungsten slug is so fragile that it can be moved only by sliding it along a surface. It is moved in this manner onto a platform of tungsten, nickel, or other suitable material having a high melting point, and while still on the platform is inserted into an electric furnace of the tube type, which is heated to about 1200° or 1300°C ., in which an atmosphere of hydrogen is maintained. This is called the baking operation. After baking, the tungsten slug may be handled without danger of breaking. At this stage, it is porous, containing about 40 per cent. voids.

The baked tungsten slug is then clamped into two electrodes, arranged in a vertical position, the bottom one of which floats in a bath of mercury cooled by a water jacket. This arrangement is necessary, because in the operations which follow, the tungsten slug shrinks, usually about 15 per cent. in length, and the mercury well must accommodate this shrinkage and still maintain electrical contact with the lower electrode. After the slug is securely clamped in the electrodes, a gas-tight housing is lowered around it and a current of hydrogen is

passed through this housing. Electric current is then passed through the slug, thus heating it to an extremely high temperature. For most purposes, a temperature of about 3000° to 3200° C. is used, and this temperature is maintained for 10 or 15 min. This may be called the sintering operation.

The sintered tungsten ingot is substantially free from voids, having a density of about 18. The two ends which were clamped in the electrodes will not have been heated to a sufficiently high temperature to cause sintering, so they are broken off and then the ingot is ready for the mechanical working process.

The working operation is begun in swaging machines,¹⁰⁻¹⁶ which operate the swaging dies. A pair of swaging dies consists of two similar blocks of high-speed steel, each block containing half the desired opening. The openings are circular in cross section. The side of the steel block containing half the desired opening is called its "face." These two half dies are placed in the swaging machine face to face, sufficiently loose so that the swaging blow can be struck, when the die halves move away from and toward each other. The machine head rotates and the dies rotate with it. Centrifugal force moves the die halves apart and rollers in the head of the machine push them together again. The dies move backward and forward several thousand times per minute. The faces of these dies must be made in a special manner for the swaging of tungsten. The portions which come in contact with the metal to be worked must be very much shorter than when swaging the ordinary metals. These are called short-faced dies. They are made of high-speed steel because they are to be used to swage hot metal.

For beginning the swaging operation on a tungsten ingot having a square or rectangular cross-section, a pair of swaging dies is selected which will just round off the corners of the ingot. The ingot is put into an electric furnace, usually consisting of an alundum tube wound with tungsten or molybdenum wire, in which an atmosphere of hydrogen is maintained. The temperature of this furnace may be as high as 1700° C. but it is more frequently in the neighborhood of 1600° C. When the ingot has attained the temperature of the furnace, one end is grasped with a pair of tongs and the other end is quickly inserted into the swaging machine. It is not possible to swage the whole length of the rod in this manner, so the ends of the rod are reversed and it is again heated, after which the unswaged end is inserted into the swaging machine. A pair of swaging dies having a somewhat smaller opening than the first pair of dies used is now put into the machine; the ingot is heated again and the swaging operations continued as before. Four or five dies are required to make a round rod from a square or rectangular ingot.

When the tungsten rod is sufficiently elongated to enable the end which first passes through the swaging machine to be gripped from the

exit side, only one heating for each pair of swaging dies is necessary. As the degree of work increases on the rod, the temperature is gradually decreased. When the working temperature has been reduced to about 1300° C., gas may be used to heat the metal preparatory to swaging. The temperature may be decreased in steps, that is, there may be a certain temperature maintained for a half dozen or more dies and then the temperature lowered for the next half dozen dies. These conditions will depend on the properties desired in the swaged tungsten rod. The swaging operation may begin on tungsten ingots of any size, but a common size is $\frac{1}{4}$ to $\frac{3}{8}$ in. square (6.35 to 9.5 mm.), and 12 to 14 in. long (30.48 to 35.56 cm.).

If it is desired to produce wrought tungsten rods more than 0.030 in. (0.76 mm.) diameter, all of the work is done by swaging. If, however, it is desired to produce tungsten wires smaller than 0.030 in. diameter, the swaging operation is resorted to only until a size of 0.030 in. or thereabouts is reached. The temperature of swaging will have been reduced as the size of the rod decreased so that the 0.030 in. rod would be swaged at a temperature of 1000° or 1100° C.

When the tungsten ingot is removed from the furnace previous to swaging, the temperature corresponds to a brilliant white heat. Tungsten oxide has not formed in the furnace because of the hydrogen atmosphere, but as soon as the ingot is removed from the hydrogen atmosphere, its temperature is such that tungsten oxide forms very rapidly, volatilizes and condenses as a white fume at some distance above the rod itself.

The tungsten ingots may also be reduced by rolling. High-speed rolls are employed and the ingot is heated to 1500° C. before each pass. Rolls are used for flat pieces and swaging machines for round sections.

The sintered tungsten ingot is as brittle as glass and extremely fragile. It is composed of equiaxed grains such as may be seen in Fig. 1, which represents the structure of a sintered tungsten ingot. When the swaging has been continued until the rectangular cross-section of the ingot has been changed to circular, the structure has been changed to that shown in Fig. 2. With still further swaging, when the tungsten rod has reached a diameter of 0.125 in. (3.2 mm.), its structure is changed to that shown in Fig. 3. At a size of 0.082 in. (2.08 mm.) its structure has changed to one corresponding to that shown in Fig. 4, while Fig. 5 represents the structure when the tungsten rod has been swaged to a diameter of 0.030 in. (0.76 mm.).

It will be seen from these micrographs that the equiaxed grains composing the sintered tungsten ingot have been progressively elongated during the swaging operations into fibers of metallic tungsten. The 0.030-in. swaged rod shown in Fig. 5 is ductile cold. It can be bent cold or it can be drawn cold.

While the tensile strength of the sintered tungsten ingot from which

this 0.030-in. swaged tungsten rod was reduced was only 18,000 lb. per square inch, the tensile strength of the rod was 215,000 lb. per square inch.

The sintered tungsten ingot was absolutely brittle, but the 0.030-in. swaged tungsten rod has an elongation of about 4 per cent. in 2 in. and a reduction in area at the point of fracture of about 28 per cent.

When it is desired to produce wires smaller than 0.030 in. diameter, a hot drawing process is resorted to. Diamond dies are usually employed for this purpose. The lubrication used, both for the swaging operations on the smaller rods and in the drawing process, is aquadag. The wire to be drawn is first passed through an aquadag mixture which is in the form of a thin paste, and then through a gas flame or other heating medium which heats the wire to the desired drawing temperature and also bakes on it a coating of the lubricant. The dies vary in size by small steps; that is, the diameter of the opening in one die will be only about 6 per cent. greater than that in the next following die.

The temperature at the beginning of the drawing may be in the neighborhood of 1000° C. and when the wire is reduced to the size of about 0.005 in. (0.127 mm.) diameter, the temperature of drawing will have been reduced to a dull red heat. Fig. 6 is a micrograph of a drawn tungsten wire. All of the tungsten wires so produced, no matter what their size, are ductile cold. The increase in tensile strength is continuous, the smallest wires being the strongest.

TABLE 1.—*Tensile Strength of Tungsten*

Kind of Material	Diam. in Mils	Tensile Strength in Lb. per Sq. In.
Sintered tungsten ingot.....	200 by 250	18,000
Swaged rod.....	216.0	50,600
Swaged rod.....	125.0	107,000
Swaged rod.....	80.0	176,600
Swaged rod.....	28.0	215,000
Drawn wire.....	18.0	264,000
Drawn wire.....	7.23	340,000
Drawn wire.....	5.78	366,000
Drawn wire.....	5.50	378,000
Drawn wire.....	3.96	483,000
Drawn wire.....	1.14	590,000

Table 1 shows the increase in tensile strength of tungsten products with the increase in mechanical working. Tungsten wire 1.14 mils diam. (a mil is 0.001 in.) shows a reduction of area at the point of fracture of about 65 per cent. Coupled with great strength, drawn tungsten wire possesses the property of ductility in the cold to a very usable degree. The wire can be coiled on mandrels having diameters but

slightly greater than that of the wire itself. It can be bent into the various shapes necessary for lamp making, and it can be handled in long lengths without danger of breaking.

Table 1 shows that the tensile strength of the 1.14-mil drawn wire is about 33 times as great as that of the sintered tungsten ingot. In ordinary metal-working processes, an increase of tensile strength of six times that of the original starting material is unusual.

GENERAL RELATIONSHIPS BETWEEN TUNGSTEN AND OTHER METALS

It should be noted from the preceding that tungsten possesses several properties different from those of the common ductile metals. For example, when the common ductile metals are worked cold or at elevated temperatures below their annealing temperatures, they are rendered more brittle at room temperature. Tungsten cannot be worked at room temperature when it is composed of equiaxed grains. When it is worked at elevated temperatures below its equiaxing temperature in such a manner as to permanently deform the grains, its ductility at room temperature increases.

When the ductile metals which have been made brittle by mechanical working at room temperature or at elevated temperatures below their annealing temperatures, are annealed, ductility is restored. When tungsten which has been made ductile by mechanical working at an elevated temperature below its equiaxing temperature is heated above the equiaxing temperature, its ductility at room temperature is lost.

The ductile metals are in their most ductile condition when they are composed of small equiaxed grains. Tungsten is in its most brittle condition when it is composed of small equiaxed grains.

When the ductile metals are heated in such a manner that coarse-grained structures are produced, they become less malleable and ductile at room temperature, as a result of the coarse-grained structures. When tungsten, however, is heated in such a manner as to produce extremely coarse-grained structures, the resulting tungsten product possesses, to a slight degree, the ability to be deformed, especially by pressure at room temperature. The utility of this type of deformability in tungsten is limited. Let us suppose, for the sake of argument, that we have a single grain of tungsten, and that we proceed to mechanically work this grain at room temperature. It becomes harder and more brittle, due to the strain hardening, and our first thought would be to heat it above its equiaxing temperature, so that it would regain its malleability and ductility. Above the equiaxing temperature this strain-hardened grain would form many equiaxed grains. We would have produced in this manner a piece of tungsten metal composed of small equiaxed grains. This material would be absolutely brittle at room temperature and no further working at room temperature would be possible. This piece of tungsten could,

however, be mechanically worked at high temperatures by the processes described above.

Molybdenum has some properties similar to those of tungsten, and others similar to those of the common ductile metals. It is in a more ductile condition at room temperature when it is composed of fine grains than when composed of coarse grains. In this respect it is similar to the common ductile metals. When its grains are deformed by mechanical working at temperatures above room temperature and below its equiaxing temperature, its ductility at room temperature increases. In this respect it more nearly resembles tungsten.

Tantalum³⁵ resembles the common ductile metals in all of its working properties. Tantalum must be very pure and especially free from hydrogen or nitrogen to be in a ductile condition. When it is melted in a vacuum, it is found to be one of the most malleable and ductile of metals. Fig. 7 is a micrograph of a cold-drawn tantalum wire which was mechanically worked at room temperature, without any annealing, from a fused globule of tantalum to a wire 0.007 in. (0.177 mm.) in diameter. This wire has not even yet reached its maximum limit of cold working. Fig. 8 shows a piece of the same wire which was heated in a vacuum to 1600° C. for 5 min. It will be noted that recrystallization has taken place. This annealed wire is much more ductile than the cold-worked wire, thus showing that in these respects tantalum is similar to the common ductile metals. Fig. 9 is a micrograph of a piece of the same tantalum wire heated for 1 min., in an atmosphere of hydrogen, to 1600° C. Recrystallization has taken place, but this wire has absorbed enough hydrogen to make it extremely brittle and fragile at room temperature. The properties of tungsten wire are the same whether heated in a vacuum or in hydrogen.

Cast zinc or worked zinc made coarse grained by a high temperature anneal may be brittle at room temperature and workable at 150° C., and after this working the ductility at room temperature will be greater than before working. It is now known that this increase in ductility of zinc is due to a substitution of a fine-grained structure for the coarse-grained one. It is known that 150° C. is above the annealing temperature of worked zinc and consequently in the hot-working region. The refinement of the grain in zinc by working at 100° to 150° C. is analogous to the breaking down of the coarse grains in a steel ingot by working above a red heat.³⁶ No amount of work on tungsten above its annealing temperature will make it ductile at room temperature.

Platinum may be produced in a coherent malleable and ductile form by the Wollaston process³⁷ without resorting to the fusion operation. There are several points of difference between the Wollaston method for producing coherent ductile platinum without fusion and the method of producing coherent ductile tungsten without fusion. The platinum has

only to be made coherent and it is inherently ductile. Tungsten has to be made coherent and then ductilized by the working process. The platinum cake immediately before working contains about 40 per cent. voids and these are welded by the working. The voids must be eliminated in tungsten before the working begins, else the material will not be workable.

EFFECT OF THORIA ON THE STRUCTURE OF SINTERED TUNGSTEN INGOTS

The principal need for thoria or other non-metallic substances in tungsten which is to be used for lamp filaments is to control the direction, and, to a certain extent, the degree of grain growth, in the filament in such a manner as to render them both rugged (not easily broken by rough handling of the lamps) and free from off-setting.* With the old type of pressed tungsten filament, the purity of the tungsten did not have to be considered except for the functioning of the tungsten wire as a lamp filament. By the present method of manufacture of lamp filaments, however, the sintered tungsten ingots must be capable of being mechanically worked hot. Therefore the addition of thoria or other non-metallic substance must be made judiciously and the heat treatment of the tungsten ingot must also be varied to suit the thoria content. Tungsten containing more than 2 per cent. thoria is difficult to work into small wires.

The effect of the thoria is to increase the resistance to grain growth at high temperatures. Other non-metallic substances will offer resistance to grain growth in proportion to the volume, arrangement and size of globules in the metal. It is difficult, however, to retain the more volatile oxides in the ingot. Even silica vaporizes almost completely during the sintering operation. Alumina volatilizes more slowly and thoria very little.

Plate 1 shows the variation in grain size of tungsten ingot with variation on the quantity of thoria, the temperature being maintained constant at about 3200° C. and the time constant—12 min. It would seem as if the resistance to grain growth had decreased in the region between 2.5 and 4 per cent. thoria. This apparent decrease in resistance to grain growth is readily explained by the germinative temperature laws.¹⁷⁻²⁶ The increase in resistance to grain growth is continuous with increase in the amount of thoria, according to the dotted portions of the curve shown in Plate 1. The germinative conditions have not produced exaggerated growth of grain up to about 1.5 per cent. thoria,

* Off-setting is the transverse displacement of a section of the filament wire. The displacement occurs at places where a grain boundary occupies the whole cross-section of the wire.

nor above about 4.5 per cent. thoria, so that the normal curve representing equilibrium grain size for the given time and temperature conditions would be independent of the exaggerated grain growth portion. These changes in grain size due to variation in the quantity of thoria can be seen plainly in the micrographs. Figs. 10, 11, 12, 13, and 14 are micrographs of the tungsten ingots containing respectively 1, 2, 3, 4, and 5 per cent. thoria. The ingots were all sintered at 3200° C. for 12 min. Figs. 15, 16, 17, 18 and 19 are micrographs of the same samples containing 1, 2, 3, 4, and 5 per cent. thoria respectively, at a higher magnification.

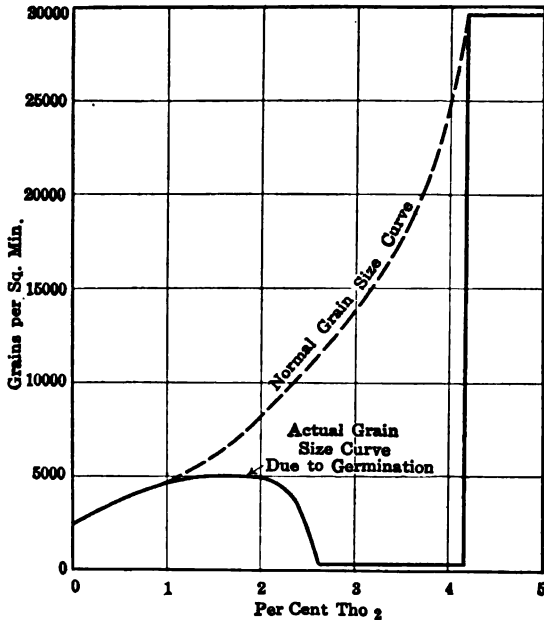


PLATE 1.—VARIATION IN GRAIN SIZE OF TUNGSTEN INGOTS WITH VARIATION IN THORIA. HEATED 12 MIN. TO MEAN TEMPERATURE OF 3200° C.

The micrographs at the higher magnification show very plainly not only the quantity of thoria, but its distribution. The thoria is present in small spherical globules in all of the samples. The number of globules is much greater in Fig. 19 than in Fig. 15. The size of the globules, however, does not vary in a marked degree.

The explanation for these coarse-grained structures with increase in resistance to grain growth is as follows: Let us take, for example, the sample containing 3 per cent. thoria. When it was heated to a mean temperature of 3200° C. by the passage of an electric current in an atmosphere of hydrogen, the axis of the comparatively long tungsten ingot would be its hottest portion. A temperature gradient would obtain from the axis to the surface of the ingot. With 1 per cent.

thoria present, even the surface of the ingot, when heated to a mean temperature of 3200°C . would permit the free growth of adjacent grains. With 3 per cent. thoria, however, the resistance to grain growth will have been sufficiently increased so that the portion of the tungsten ingot near the surface will be below the temperature of free grain growth. The portions nearer the axis, being hotter, will permit grain growth to take place. There will be a sharp boundary line between that portion of the ingot in which grain growth could take place and that portion in which growth was not possible (or at least could take place but slowly) under the existing conditions. The grains in the growth range will be larger than those in the inert range. At the boundary between the growth and inert grains, the former, because of their larger size, will be able to absorb the latter, which cannot coalesce with one another because they are (1) too nearly the same size, and (2) too cold. Adjacent grains in the growth range away from the boundary between the growth and inert grains, cannot coalesce freely with one another because they are too nearly the same size. Their size, however, is considerably greater than that of the grains in the inert region. The grains at the boundary between the inert and growth regions become germinant grains. They increase their size by absorption of the inert grains until they are much larger than the hotter grains in the growth region, which they then absorb. The resulting structure will be an extremely coarse-grained one, with a general tendency for the grains to be radial, much as if the ingot had solidified in a mold from the molten condition.

In the sample containing 2.5 per cent. thoria, germinant grains were formed first at a lower temperature, because the resistance to grain growth would be less with 2.5 per cent. than with 3 per cent. thoria. With the same average temperature, the germinant grains in the 2.5 per cent. thoria sample would first form nearer the surface of the sample. This is exactly what was observed. With the sample containing 4 per cent. thoria, the germinant grains would first form in a hotter portion of the ingot. It was observed that the germinant grains did form initially in the 4 per cent. thoria ingot practically at its axis. This indicates that with the 4 per cent. thoria ingot at a mean temperature of 3200°C . the region of free grain growth occurs only in the hottest portion of the ingot and all other parts of the ingot are in the inert range. With 5 per cent. thoria, no part of the ingot is sufficiently hot with a mean temperature of 3200°C . for free grain growth to take place in a time period of 12 min., so the whole cross-section of the ingot is in the inert range. The samples containing 1 and 2 per cent. thoria, at a mean temperature of 3200°C . were sufficiently hot for the whole cross-sections to be above their germinative temperatures, that is, to be entirely within the growth range. It will be noted that the 2 per cent. thoria sample is finer grained than the 1 per cent. sample and the sample containing 5

per cent. thoria is the finest grained of them all. It will be noted also in these samples that where grain growth has taken place the thoria globules have not apparently changed in position. For example, in Fig. 17 a portion of one grain only is shown. The thoria globules, however, are distributed within this grain in a manner very similar to the distribution of the thoria globules in Fig. 19, which consists of a fine-grained structure with the thoria globules largely situated at the boundaries of the small grains.

Some calculations indicate that the difference in temperature between the surface of the tungsten ingot $\frac{1}{4}$ in. (6.35 mm.) square and its axis is about 150° C. when a mean temperature of 3200° C. is maintained by the passage of electric current through the ingot.

By heating these samples for various time periods, the history of grain growth can be studied. In the growth range, an apparent equilibrium grain size is reached within a few minutes at a high temperature, say 3200° C. At lower temperatures around 2600° and 2700° C. a longer time is needed in order to produce an apparent equilibrium grain size. Under germinative conditions, if the germinative temperature is high, the velocity of grain growth is rapid, and if the germinative temperature is low, the velocity of grain growth is slow. At a temperature of 2600° C. the rate of grain growth was only about one-twentieth of the rate at 3200° C.

The sintering together of the individual particles of tungsten, or their welding, is an entirely distinct operation from their coalescence. At a temperature of about 2400° or 2500° C., sintering takes place and is complete within a few minutes. Most of the voids have been closed and most of the shrinkage of the ingot takes place during the sintering. With increase in temperature, these small grains formed by the sintering operation commence their growth. If no germinative temperature condition is encountered, the grains will increase in size with increase in temperature, and up to a certain point with increase in time of exposure. Germinative conditions, however, may change the order of grain size enormously.

When the germinative temperature is maintained at a point about midway between the axis and the surface of an ingot, the large germinant grains grow both toward the surface, absorbing the inert grains, and toward the axis, absorbing the grains which are in approximate equilibrium with each other. At the boundary lines between two large germinant grains and a fine-grained region, there will always be, if the fine-grained region is considered as a sea and the coarse-grained region as land, a bay at the intersection of the two large grains with the fine-grained region. This indicates that the two large grains may be competing for the small grains at this point. The forces of attack will act in

different directions and a sort of neutral zone in which grain growth is less rapid than normal will obtain. Fig. 20 shows this phenomenon.

Tungsten ingots made up of an aggregate of large and small grains are not easily worked. They are apt to crack at low temperatures along the grain boundaries, between the large grains or at boundaries between large- and small-grained areas.

EFFECT OF CHANGE OF TEMPERATURE ON THE STRUCTURE OF TUNGSTEN INGOTS

Since a temperature of 3200°C . produces the germinative conditions at the axis of a tungsten ingot containing 4 per cent. thoria, a fine-grained structure would be produced by heating to temperatures lower than about 3150°C . The germinative temperature of a tungsten ingot containing 5 per cent. thoria, or more, is theoretically above the melting point of tungsten, so it is non-existent.

A tungsten ingot containing 2.5 per cent. thoria has its germinative temperature near the surface of the ingot when a mean temperature of 3200°C . is maintained. Therefore, if the temperature were lowered to about 3100°C ., the germinative temperature would occur near the axis in this sample. If, however, the temperature could be increased to 3300°C . before germination had begun during heating, a fine-grained structure would result, which would correspond to the normal equilibrium grain size in the growth range for the given time and temperature conditions.

With the sample containing 1.5 per cent. thoria, a mean temperature of 3200°C . was sufficient to make every part of the cross-section of the ingot above its germinative temperature. If the temperature could have been lowered to, say, 2900°C ., germinative conditions would have obtained in this sample with the resultant production of a coarse-grained structure. The germinative temperature of tungsten ingots containing 0.75 per cent. thoria is about 2550° to 2650°C . This germinative temperature is so low for tungsten that the individual particles of the tungsten powder must be very small or the formation of large grains at the germinative temperature will be defeated.

Some tungsten powder was prepared consisting of grains or particles very much smaller than the size usually employed. Experiments were made with tungsten ingots pressed from this very fine tungsten powder. It was found that the germinative temperature occurred at about 2600°C . The time necessary to produce a marked coarsening of the grain at the germinative temperature was very much longer in this material than with material whose germinative temperature was in the neighborhood of 3200°C .

Fig. 21 represents the fracture of one of these tungsten ingots heated for 20 min. at a temperature near 2600°C . Fig. 22 is the fracture of an

ingot treated at a temperature of about 2600° C. for 30 min. In both of these photographs, the coarse-grained areas can be seen in the region midway between the axis and the surface of the sample. The axis itself is fine-grained and the surface is fine-grained.

Fig. 23 is a fracture of one of these tungsten ingots which was heated quickly to a temperature of 3200° C. and held for 30 min. The structure is fine-grained and uniform.

Fig. 24 is a micrograph of a tungsten ingot held at 2600° C. for 20 min.

Fig. 25 shows the cross-section of an ingot heated to about 2600° C. for 30 min. The fine-grained portions near the surface in both these samples is finer grained than that near the axis.

Fig. 26 is a longitudinal section through section A-A of the same ingot as Fig. 25.

Fig. 27 shows how the germinative temperature conditions produce coarse-grained structures at the ends of the ingots which are held in the electrodes. There is a temperature gradient at the ends of the ingots, because the electrodes are either directly or indirectly water cooled so that a change of temperature of at least 2000° is maintained between the portion of the ingot held in the electrode clamp and the hottest portion. Fig. 27 shows where the germinative temperature existed. To the left of the coarse-grained region may be seen the inert region, and to the right the gradual change of the coarse-grained area to a normal fine-grained structure. It is needless to say that the sintering temperature of this ingot was far above its germinative temperature.

Fig. 28 shows the structure of a tungsten ingot, heated quickly past the germinative temperature and held there for 30 min. Any intermediate structure between the coarse-grained structure formed at the germinative temperature and the normal fine-grained structure formed by heating quickly through the germinative temperature range can be produced by varying the time in which the ingot remains in the germinative temperature range during heating—that is, by varying the rate of heating.

Fig. 29 and 29A are micrographs of a tungsten ingot which was held for 20 min. at 2600° C., and then heated quickly to 3200° C. and held there for 10 min. The grain size of this sample is very much coarser than the normal grain size formed by rapid heating through the germinative temperature range and much finer than the grain size which was formed by a long sojourn in the germinative temperature range.

The smallest grain size that can be produced in an ingot will depend upon the size of the tungsten particles composing the tungsten powder. At the time these particles weld themselves together (sinter), the smallest grain size which it is possible to obtain from this tungsten powder will result. A tungsten ingot in this condition, however, finds very

little use in the industries. It is too fine-grained to be easily amenable to the tungsten working process, especially when it is desired to secure a great amount of permanent deformation. For example, a tungsten ingot treated in this manner can only be swaged and drawn with the greatest difficulty from an ingot $\frac{1}{4}$ in. square to a small drawn wire. Such a metal is so hard that the diamond die wear may be 50 times as great during drawing as that of tungsten ingots composed of larger grains.

By heating the tungsten ingot just above the germinative temperature, the smallest grain size in the growth range is produced. It is only in the growth range that the tungsten ingots lend themselves readily

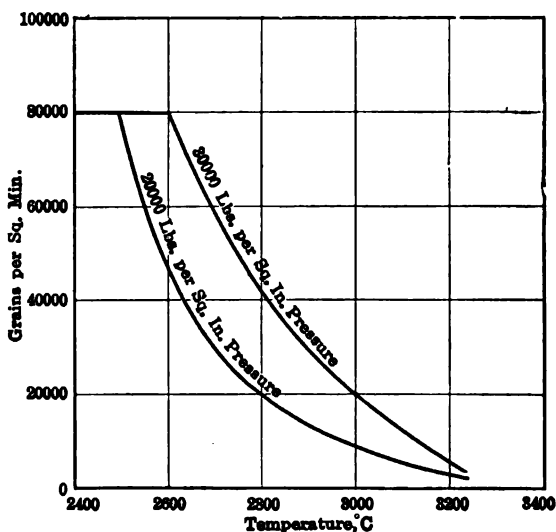


PLATE 2.—GRAIN-SIZE TEMPERATURE CURVES OF TUNGSTEN BRIQUETS. FIGURES REFER TO INITIAL PRESSURE USED IN BRIQUETTING. TIME OF HEATING, 12 MIN.

to the mechanical working process. As the temperature increases, the grain size of the tungsten ingots increases up to the melting point of the tungsten.

The relatively coarse tungsten powder ordinarily employed in the manufacture of tungsten ingots is sufficiently coarse grained to mask the germinative temperature phenomena in the 0.75 per cent. thoria ingots during sintering. In these ingots, the grain size starts at a minimum at about 2600° C. and gradually increases up to the melting point. A typical set of results is shown in Plate 2. The curves show the variation in grain size in tungsten ingots due to variation in the pressure to which the tungsten powder is subjected, and to variation in the temperature to which the tungsten is heated. We may call a pressure of 30,000 lb. to the square inch a normal pressure. The grain size of an ingot

sintered for 12 min. at 2500° C. will be about 80,000 gr. per square millimeter. At 2600° C., the grain size is the same. This indicates that below 2600° C. tungsten containing 0.75 per cent. thoria is in its inert range. The grain size will become progressively larger as the temperature is increased above 2600° C., so that at 3200° C. a grain size of 5000 per square millimeter or less will usually result with tungsten metal containing 0.75 per cent. thoria.

By increasing the pressure used in making the compressed tungsten slug to 200,000 lb. per square inch, the grain size becomes larger for any given temperature of treatment, as shown in Plate 2. The use of 200,000 lb. pressure in practice, however, is not only an extremely difficult task to perform but it is absolutely unnecessary for the accomplishment of any given purpose; for example, any result produced with 200,000 lb. per square inch pressure can be duplicated at a higher temperature with a smaller pressure.

The tungsten powder is partly amorphous and partly crystalline. The crystalline particles are probably strain-hardened by the pressure, but these strains play little part in the grain growth. They are removed before sintering takes place. The reason that high pressure tends to make larger grains is that the tungsten particles are pressed into more intimate contact, thus facilitating grain growth.

By comparing Plates 1 and 2, it will be observed that the increase in resistance to grain growth of about 4 per cent. thoria is equivalent to the decrease in resistance to grain growth due to lowering the temperature about 300° C.

CHANGES IN GRAIN SIZE DUE TO INCOMPLETE FUSION OF TUNGSTEN INGOTS

Tungsten ingots containing about 0.75 per cent. thoria remain comparatively fine grained even up to the melting point. Fig. 30 is a micrograph of one of these ingots in which the central portion has fused and resolidified and the outer portion has remained entirely in the solid state. Fig. 30A represents the same structure at a higher magnification. We have been taught that when fused metal at the time of solidification is in contact with crystalline metal of the same composition, this latter will act as a nucleus about which the molten metal will crystallize and assume the same orientation as the crystalline nucleus. In Fig. 30, when the tungsten was molten, it was in contact with hundreds of the small grains composing the unfused portion of the ingot. When solidification began, why did not each one of these small differently oriented grains act as a nucleus for the crystallization of the molten tungsten? They probably did. If the crystallization of the fused tungsten began from many points with different orientation, why was the resulting struc-

ture so coarse-grained as that shown in Fig. 30? The answer in my opinion is as follows: When a molten metal is in the process of solidification, it is in its most susceptible condition for grain growth. In other words, the possibility of one grain absorbing adjacent grains in an almost inconceivably short time is greater at the melting point of a metal than at any other temperature. Let us suppose that the crystallization of this fused tungsten began at the contact between the fused and the unfused portion. This must necessarily have been the case. The small grains would grow axially and if no grain growth could take place during the solidification, each of these grains would form a wedge, the small end being at the axis of the ingot. This has not taken place. Some of these grains having advantages over their neighbors, have acquired crystalline material from the molten metal faster than others. These more vigorous grains have shot out arms perpendicular to their axes of growth and have absorbed not only the molten metal which should have gone to some of the other nuclei, but also some of the crystalline material which had solidified on other nuclei. In this manner only a few of the more vigorous grains have survived.

Fig. 31 shows that if the original structure of the ingot is coarse-grained instead of fine-grained, the fused central portion will resolidify strictly in accordance with the laws of the initial nuclei. For example, it will be seen that every grain in the unfused portion has its continuation in the portion which fused and subsequently resolidified. There is no reason to suppose that at the beginning of solidification of Fig. 30, crystallization did not start from each and every small grain which was in contact with the fused metal. This leads us to the conclusion that in cast metals, the grain size does not depend entirely on the number of nuclei from which crystallization begins, but that grain growth takes place at a remarkably fast rate during solidification.

Tungsten and Carbon

Tungsten in the presence of carbonaceous gases at high temperatures, or in contact with solid carbon at high temperatures, forms tungsten carbide, generally W_2C . Tungsten containing even small amounts of tungsten carbide at the boundaries of the grains is extremely brittle and fragile both at room temperature and at high temperatures. It has not been possible to mechanically work tungsten ingots containing tungsten carbide as a net work. Fig. 32 is a micrograph of a tungsten ingot made by adding 0.9 per cent. carbon in the form of lamp black to the tungsten powder before pressing. The tungsten carbide is the lighter constituent surrounding the grains of pure tungsten. This material is brittle, both hot and cold.

When too much carbon is added, the tungsten ingot, especially if

thoria is present in the tungsten powder, will burst during the sintering operation. Fig. 33 is a photograph showing one of the bursted ingots containing carbon and a normal tungsten ingot without carbon.

If a piece of tungsten metal is heated to a temperature of $1800^{\circ}\text{C}.$, in contact with solid carbon or in the presence of carbonaceous gases, tungsten carbide forms readily at the surface of the sample. Carbon containing gases will act more quickly and at lower temperatures than solid carbon. Hydrocarbons may form tungsten carbide in contact with metallic tungsten at temperatures as low as $1100^{\circ}\text{C}.$ Fig. 34 shows a piece of tungsten that was heated for 1 hr. in an electric furnace in an atmosphere of CO. The lighter portion is the tungsten carbide which forms on the surface. The darker portion is pure tungsten. Fig. 35 shows a piece of tungsten metal heated for $1\frac{1}{4}$ hr. at a temperature near $1800^{\circ}\text{C}.$, the tungsten being placed on a platform of carbon while an atmosphere of hydrogen was maintained in the furnace. The lighter portion is tungsten carbide. The depth of carbonization increases with increase in time. In $1\frac{1}{4}$ hr. the depth of carbonization was 0.21 mm. and in 3 hr. 0.30 mm. at $1800^{\circ}\text{C}.$

It has been found possible to mechanically work tungsten containing a considerable amount of tungsten carbide when the carbide was made separately, powdered, and added to the tungsten powder before pressing. Tungsten ingots made up containing tungsten carbide in this manner may be mechanically worked when the carbon content is far in excess of that necessary to make the tungsten brittle ordinarily. When added in this way, the tungsten carbide does not surround the tungsten grains.

GENERAL CONSIDERATIONS REGARDING THE WORKING PROPERTIES OF TUNGSTEN

The sintered tungsten ingots are usually comparatively fine grained, say from 1500 to 5000 gr. per square millimeter. It is considered desirable at present to keep the grain size of the ingots comparatively small because the inherent resistance to grain growth will usually give better life properties to the tungsten wire when used for lamp filaments. It is easily possible, however, to get the grains too fine for proper mechanical working. The more thoria or other non-metallic materials present, the more does fineness of grain militate against the mechanical working. With 0.75 per cent. thoria, which is the amount ordinarily used, if the grain size in the ingot is more than about 7000 per square millimeter, the metal will be extremely hard to work, especially in the smaller sizes. It is usually advisable to keep the grain size below 6000 per square millimeter. Tungsten ingots have been worked containing as high as 30,000 gr. per square millimeter, but the metal is so hard that it is impractical to work it as a commercial process.

With very coarse-grained structures—for example, with ingots containing grains each of which measures several square millimeters in area—the first stages of the mechanical working process are very apt to break the metal. If one of these coarse-grained ingots passes the first eight or ten pairs of swaging dies, the rest of the working process is comparatively easy—in fact, easier than the working of the tungsten rods made from finer-grained ingots.

If it is desired to produce ductility in tungsten with a comparatively small amount of working, the following processes may be resorted to:

1. The working should be carried on at as low a temperature as possible.
2. The grain size of the ingot should be as small as will permit mechanical working without causing excessive trouble.

Either method, or both of the methods carried out simultaneously, will produce the desired effect, but the resulting product, which has been made ductile with a minimum amount of mechanical working, is not a suitable material for further mechanical working. It will be so hard that it will wear the dies unduly, and, furthermore, it will break and split easily during the working. What is more apt to be desired than the production of ductility in tungsten with a comparatively small amount of mechanical working is the possibility of working the tungsten a great deal before it becomes too hard and intractable for further working. This end is accomplished in several ways:

1. The grain size of the sintered tungsten ingot should be less than about 6000 gr. per square millimeter.
2. The working temperature at the beginning of swaging should be very high, say 1700° C.
3. The initial swaging temperature may be considerably lower and the swaged tungsten rod can be subjected at intervals to a heating process which will cause the distorted grains formed by working to change into equiaxed grains, thereby forming a structure usually somewhat coarser-grained than that of the ingot. The equiaxed tungsten rod is then capable of a greater amount of mechanical working at the proper temperature than it would have been had it not been equiaxed.

If it is desired to produce a piece of tungsten which is ductile at a particular size, this may be accomplished in the following ways:

1. By starting with a coarse-grained material of such a size that it will take a considerable amount of mechanical working to reduce it to the desired size.
2. By starting with a fine-grained material of such a size that a moderate amount of mechanical working, say an elongation of 25 times its original length, will reduce it to the desired size.
3. By starting with smaller sizes than would be used with (1) and

(2) and performing the mechanical working operations at temperatures as low as possible.

The reasons for the above generalities have been largely ascertained and will be considered later.

From the time the tungsten wire reaches a diameter of 0.030 in. (0.76 mm.) or less, it is handled on reels. It would not be at all convenient, at any stage in the fine-wire manufacture, to heat it to such a temperature that the fibrous structures to which tungsten owes its ductility are destroyed. Such an operation would make the wire brittle and it could not be handled on reels in lengths of a mile or more at room temperature (as is done now) but would have to be handled in comparatively short lengths. This would slow up production to such an extent that it could not be tolerated.

Let us suppose that we have two tungsten ingots made from the same tungsten powder but that one of them has been sintered at the germinative temperature and, therefore, is coarse grained. Let us suppose that the other ingot has been sintered at a temperature above the germinative temperature and consequently is fine grained. Ingots of this nature have been made, in which the grain size was 50,000 times as great in the coarse- as in the fine-grained sample. These two ingots can be worked and treated in such a manner that when small wires are produced from them, they will be practically identical in structure. Both ingots are first swaged until their length has been about doubled or has reached some other suitable length; then these swaged rods are heated in an atmosphere of hydrogen by the passage of an electric current to a temperature above that of equiaxing. The result in an individual case was as follows:

Before treatment, the grain size ratio in the two ingots was 50,000 to 1; after swaging to 100 per cent. elongation and reheating to above the equiaxing temperature, the grain size ratio was 4:1. Fig. 36 shows a longitudinal section of the fine-grained ingot after swaging and reheating, and Fig. 37 a longitudinal section of the coarse-grained ingot after swaging and reheating. After an additional swaging and reheating, the grain size of the two rods will be practically identical. This process can be used to equalize the structures of the tungsten rods when desirable. Fig. 38 is a typical example of a longitudinal section of a swaged tungsten rod. Fig. 39 is a micrograph of a similar tungsten rod after heating for 3 min. to a temperature of 3100° C.

Tungsten rods which have been worked and recrystallized are stronger than sintered rods. In the sintered rods, the grains are exactly equiaxed, but in the recrystallized rods the grains are longer in a longitudinal than in a transverse direction.

Equiaxing Temperature of Worked Tungsten

The equiaxing temperatures of worked tungsten have been determined with an exposure of 5 min. The equiaxing temperature of a swaged tungsten rod which has been reduced in area by working about 24 per cent. is 2200° C. The equiaxing temperatures are gradually lowered both as the degree of deformation increases and as the temperatures of working decrease. Both of these factors serve to give tungsten a long equiaxing temperature range. When the swaging process has been carried on so as to reduce the area by working about 90 per cent., the equiaxing temperature is 1800° C. for a period of 5 min. With the very small tungsten wires which have been reduced in area 99.99 per cent. or more, and which have been finished at a comparatively low temperature, say a dull red heat, the equiaxing temperature in a period of 5 min. will be in the neighborhood of 1350° temperature. The equiaxing temperature also decreases as the time of exposure increases.

Germinative Temperature Phenomena in Worked Tungsten

When most metals have their grains permanently deformed, a slight amount, say corresponding to a reduction of area of 1 per cent. or more, but usually not more than 20 or 30 per cent., germinative temperature phenomena are apt to render them coarse grained during a normal annealing process. With ordinary muffle heating, there is apt to be no temperature gradient, or at most a very slight one, and a moderate deformation will cause within the metal a strain gradient which will cause germinative grains to form at suitable temperatures with the consequent production of coarse-grained structures.

When tungsten is deformed a moderate amount, say a few per cent. reduction in area, it should form these coarse grains at its germinative temperature, and it probably would if it were heated in a muffle to a temperature of about 2300° or 2400° C. When such a piece of tungsten, however, is heated by the passage of an electric current, the strain gradient has its maximum strain near the surface of the sample (at the point of application of the deformational forces) and the point of minimum strain is at the axis of the tungsten rod. When this rod is heated by passing an electric current through it, its axis is heated to a higher temperature than its surface. The temperature gradient, therefore, serves to counterbalance the strain gradient in such a manner as to defeat the formation of coarse grains.

As the degree of deformation increases, however, the strain gradient from surface to axis of the tungsten rod becomes practically nil. The temperature gradient during heating or during a sojourn at a certain high temperature will still obtain. Germinative temperature phenomena

are then apparent in worked tungsten. When a tungsten rod has been swaged from 0.250 in. (6.35 mm.) to 0.080 in. (2.03 mm.), coarse grains can be produced by maintaining the 0.080-in. rod at a temperature just above that of equiaxing for an extended period of time. Coarse grains may also be produced in these 0.080-in. swaged rods by heating gradually with electric current to a very high temperature. Fig. 40 is a micrograph of a sample of 0.080-in. swaged tungsten rod heated to a temperature of 3100° C., the time of heating being about 10 sec. Fig. 41 shows a piece of the same 0.080-in. swaged tungsten rod which was heated as quickly as possible to 3100° C. It will be noted that the sample that was heated quickly is comparatively fine grained and the sample that was heated more slowly is extremely coarse grained. The sample shown in Fig. 41 can be maintained at a temperature of 3100° C. for hours without changing its grain size noticeably. This shows that a variation in the change of rate of heating of 10 sec. may have more influence on the resulting grain size than an exposure of many hours, or even many days, at the highest temperature reached. All rates of heating requiring more than 10 sec. to reach 3100° C. will produce coarse-grained structures in these 0.080-in. rods. The heating of an 0.080-in. swaged tungsten rod to a temperature of 2800° C. in a period of 10 sec. or more will result in a coarse-grained structure.

It should be noted in this respect that the presence of thoria in swaged tungsten operates against the formation of these large grains. It should also be noted that all of the heating is done by passing electric current through the metal itself in an atmosphere of hydrogen, thus causing a temperature gradient to exist in the heated sample. These examples of rapid grain growth are with tungsten ingots containing no thoria.

At a temperature of 2750° C., the rate of heating must be 11 sec. or more in order to produce the coarse-grained structure. At a temperature of 2700° C., if the time of reaching that temperature is less than 7½ min., the structure will be fine grained, whereas if the time is more than 7½ min., the structure will be coarse grained. At a temperature of 2600° C., the time of heating to that temperature must be more than 20 min. in order to produce a coarse-grained structure. In these remarks, a coarse-grained structure indicates the very coarse-grained structure produced under exaggerated grain-growth conditions. These time periods will also change with the particular material used.

If the 0.080-in. tungsten wire is held at a mean temperature slightly above the equiaxing temperature for an extended time, large grains will form according to the regular germinative temperature law. Fig. 42 will illustrate this grain growth at constant mean temperature, and a constant temperature gradient. This is a micrograph of an 0.080-in. swaged tungsten rod which has been reheated to a comparatively high temperature. The micrograph shows that portion which was held in

the electrode clip and also the portion near the clip. It will be seen that on the left of the micrograph the grains are deformed. This was obviously the coldest portion. Temperature gradients in two directions would obtain near the electrode clip. There would be an axial temperature gradient and a radial one. The portion at the extreme right of the micrograph was above the germinative temperature and this portion exhibits a rather uniform grain size throughout. At all portions, however, between the unrecrystallized portion and the extreme right of the micrograph, the germinative temperature has existed in some part of the rod. In the hotter zone, the germinative temperature has been near the surface, and in the cooler regions, near the axis of the rod. The germinative temperature areas can be seen readily in this micrograph, although sufficient time was not given for the germinative temperature regions to encroach upon the smaller grains of either the hotter or colder portions of the sample. This figure, therefore, represents the first stages of grain growth in the germinative temperature region. Fig. 43 is a micrograph of a similar sample after the germinative grains have reached a larger comparative size. Fig. 44 is a micrograph of the same sample as Fig. 43 in the hotter portion which was above the germinative temperature. It will be noted that the colder germinative temperature portion has produced larger grains than the hotter portion which was above the germinative temperature.

When an 0.080-in. swaged tungsten rod is held at its germinative temperature, it takes considerable time for the coarse grains to form on the entire cross-section of the rod. As the size of the tungsten wire becomes smaller, sometimes a few seconds at the germinative temperature is sufficient to cause the formation of coarse-grained structures. The presence of thoria also impedes the formation of large grains in these small tungsten wires.

Table 2 shows the minimum time required to change tungsten wires originally possessing fibrous structures to coarse-grained structures, and also the variation in the diameter of wire and in the temperature to which it is heated. The tungsten wires used in these experiments did not contain thoria. The thoriated wires sometimes take as long as 1000 or 1500 hr. to change into the coarse-grained structures unless the temperature be maintained at the germinative temperature. In this event, a few hours only are required to form the coarse-grained structure. It should be noted from Table 2 that tungsten wires 0.004 in. in diameter form coarse-grained structures easily, whereas tungsten wires 0.005 in. in diameter or greater seem reluctant to form the coarse grains when the temperature is maintained constant either at or above the germinative temperature. The coarse grains form more quickly at the germinative temperature than they do at higher temperatures, but there is a marked difference in time required to form the coarse-grained structures at the

germinative temperature between the tungsten wires less than 0.005 in. (0.127 mm.) diameter, and more than 0.005 in. diameter.

TABLE 2

Diam. of Wire in Mils	Temperature in °C.	Minimum Time Required to Change to Coarse-grained Structure	
		Minutes	Seconds
3	3,100	3	0
3	2,900	2	45
3	2,800	2	0
3	2,700	0	45
3	2,650	0	30
3	2,600	0	7
3	2,550	0	20
3	2,500	0	20
4	3,100	more than 2	30
4	2,900	3	0
4	2,800	3	0
4	2,700	2	45
4	2,650	2	45
4	2,600	2	45
4	2,550	1	45
4	2,500	1	0
5	2,900	13	0
5	2,800	more than 30	0
5	2,700	more than 30	0
5	2,650	more than 28	0
5	2,600	more than 40	0
5	2,550	more than 60	0
5	2,500	more than 40	0
6	2,900	more than 30	0

In the smaller tungsten wires, say below 0.005 in. diameter, containing no thoria, it will be noted that coarse-grained structures are formed in comparatively short time periods when the temperature is raised above the germinative temperature very quickly and maintained above the germinative temperature. The coarse grains form more readily, however, in these wires at the germinative temperature than at higher temperatures. Furthermore, a slow heating through the germinative temperature range will produce coarse-grained structures very much more readily than a rapid heating past the germinative temperature range followed by a sojourn at the higher temperature. If the diameter of the wire is more than about 0.005 in., the easiest way to form the coarse-grained structures is by slow heating through the germinative temperature range followed by a sojourn at a higher temperature. It can be seen from Table 2 that it may take as long as an hour to form coarse-

grained structures with wires 0.005 in. or greater in diameter either when held at the germinative temperature or above it. Coarse-grained structures in these samples, however, can be produced in a few seconds by heating the wire slowly through the germinative temperature range.

Fig. 45 is a typical example of the fine-grained structures produced in these experiments and Fig. 46 is a typical example of the coarse-grained structures.

The formation of coarse-grained structures during a gradual heating through the germinative temperature range needs further consideration here. The effect of heating so quickly that germination does not have time to assert itself in the germinative temperature range has already been considered. In the pressed tungsten slug, for example, a heating period of 6 min. can be used to attain the highest temperature without any exaggerated grain growth. Some of the swaged tungsten rods, however, and also the small drawn wire, must be heated through the germinative temperature range in less than 10 sec. to defeat the formation of the coarse-grained structures. The germinative temperature will be lower as the time of heating is increased. For example, if a tungsten wire is heated by electric current to a temperature just above that of equiaxing and held there for an indefinite time, coarse grains will be formed for reasons discussed above. If, however, the tungsten wire is held at a temperature several hundred degrees above the equiaxing temperature for a short time, a coarse-grained structure may be produced in a shorter time. If the tungsten rod is heated to a temperature far above that of equiaxing, fine grains will first form. They may change to large grains due to normal grain growth, but not by germination; or they may remain as small grains.

The equiaxing temperature is a function of the time, and consequently the germinative temperature which depends to a certain extent upon the equiaxing temperature will also be a function of the time. If we could heat a piece of cold-worked copper to 1000° C. and cool it again to room temperature, the whole cycle taking but a millionth of a second, we would find that the structure of the wire had not been materially changed nor would the properties at room temperature be changed. In other words, cold-worked copper which will recrystallize or equiax at a temperature of 250° C. if sufficient time be given, will not equiax or recrystallize in a millionth of a second at a temperature 750° higher. Experiments of this nature have been conducted on tungsten wire. The wire can be flashed to a temperature near its melting point and quickly cooled to room temperature without apparent change in its structure or properties. Recrystallization of deformed grains involves a certain time period. If the temperature is comparatively low, the time is long, and *vice versa*.

When a fibrous tungsten wire is heated at a rapid rate by means of

electric current, but not so rapid that the germinative temperature laws are masked, germinant grains will form at some temperature depending upon the rate of heating. These germinant grains should be able to absorb both hotter and colder smaller grains faster than these smaller grains can coalesce with one another. When this condition obtains, coarse-grained structures will result. The gradual rise in temperature favors the absorption of the smaller grains by the larger germinant grains. The grain growth becomes a race between the germinant grains and the smaller grains. This race is in its critical period at the beginning of germination. After the germinant grains have once acquired a size much larger than the mean size of the smaller grains, the latter are absorbed readily at any temperature in the grain-growth region.

Another example of germinative temperature conditions is shown in Fig. 47, a micrograph of a molybdenum hook used to support tungsten filaments in electric incandescent lamps. This hook was in the fibrous condition when it was put in the lamp. It has been heated in the lamp from the heat of the tungsten filament which it supported and with which it was in contact at one point only, namely, at the bottom of the loop portion. It received heat by conduction and radiation from the coiled tungsten filament. There would be temperature gradients in two directions in this wire, one axially and one radially. The combination of these two temperature gradients has produced the structure seen in Fig. 47. It will be noted that at the point of contact between the tungsten wire and the molybdenum hook, the latter is fine grained. The temperature at this point was above the germinative temperature. At points more remote from the point of contact between the hook and the filament, there is every gradation in structure from fine grained throughout to coarse grained throughout. At the contact between the recrystallized and unrecrystallized portion (shown at the extreme right of Fig. 47) the molybdenum hook is very brittle. It is ductile in the fully recrystallized region and also in the unrecrystallized region.

THE EFFECT OF TIME AND TEMPERATURE ON THE GRAIN SIZE IN TUNGSTEN

A series of experiments was carried out on swaged tungsten rods 0.075 in. diameter made from tungsten metal of three different varieties. Two of the sets of samples contained 0.75 per cent. thoria and the third set contained no thoria. The results of these experiments are given in Table 3.

This table shows plainly that the increase in grain size with increase in time is not regular. It is as regular, however, as might be expected with different samples. At the time these experiments were carried out, the writer was not aware of the extreme rapidity of the formation

of germinant grains during heating. Some of the radical results indicated in Table 3 were found later to have been caused by the germinative temperature conditions during heating.

TABLE 3

Kind of Metal	Temperature °C.	Time of Exposure			Grains per Square Millimeter
		Hrs.	Min.	Sec.	
(A) $\frac{3}{4}$ per cent. thoria....	2,500	0	0	30	3,400
$\frac{3}{4}$ per cent. thoria....	2,500	0	1	0	2,700
$\frac{3}{4}$ per cent. thoria....	2,500	0	5	0	2,700
$\frac{3}{4}$ per cent. thoria....	2,500	0	25	0	2,200
$\frac{3}{4}$ per cent. thoria....	2,500	2	0	0	3,000
$\frac{3}{4}$ per cent. thoria....	3,000	0	0	30	2,300
$\frac{3}{4}$ per cent. thoria....	3,000	0	1	0	2,200
$\frac{3}{4}$ per cent. thoria....	3,000	0	5	0	2,500
$\frac{3}{4}$ per cent. thoria....	3,000	0	25	0	1,800
$\frac{3}{4}$ per cent. thoria....	3,000	2	0	0	2,300
$\frac{3}{4}$ per cent. thoria....	3,000	9	45	0	2,200
(C) No thoria.....	2,500	0	0	30	1,700
No thoria.....	2,500	0	1	0	1,900
No thoria.....	2,500	0	5	0	2,800
No thoria.....	2,500	0	25	0	1,000
No thoria.....	2,500	2	0	0	1,600
No thoria.....	3,000	0	1	0	900
No thoria.....	3,000	0	5	0	1,500
No thoria.....	3,000	0	25	0	1,100
No thoria.....	3,000	2	0	0	900
(D) $\frac{3}{4}$ per cent. thoria....	2,500	0	0	30	2,000
$\frac{3}{4}$ per cent. thoria....	2,500	0	1	0	2,300
$\frac{3}{4}$ per cent. thoria....	2,500	0	5	0	1,700
$\frac{3}{4}$ per cent. thoria....	2,500	0	25	0	2,100
$\frac{3}{4}$ per cent. thoria....	2,500	2	0	0	1,800
$\frac{3}{4}$ per cent. thoria....	2,500	9	45	0	1,600
$\frac{3}{4}$ per cent. thoria....	3,000	0	0	30	1,900
$\frac{3}{4}$ per cent. thoria....	3,000	0	1	0	2,000
$\frac{3}{4}$ per cent. thoria....	3,000	0	5	0	1,900
$\frac{3}{4}$ per cent. thoria....	3,000	0	25	0	2,000
$\frac{3}{4}$ per cent. thoria....	3,000	2	0	0	1,700

The conclusions reached from the results given in Table 3 are as follows:

1. Recrystallization is complete in less than 30 sec. at temperatures of 2500° C. or above. Aside from the germinative temperature phenomena, grain growth has established an approximate equilibrium grain size at the end of 30 sec. Further heating for 9 $\frac{3}{4}$ hr. increases the grain size but slightly.

2. In the tungsten rods containing thoria, the difference in grain

size between a temperature of 2500° C. and a temperature of 3000° C. with the time period constant is very slight.

3. With tungsten containing no thoria, the difference in grain size for a given time between 2500° C. and 3000° C. is more marked.

Tungsten ingots during sintering also attain an approximate equilibrium grain size for a given temperature in a few minutes. This is especially true at the higher temperatures of sintering, say 3200° C., whereas if the sintering is done at a lower temperature, a longer time is necessary for an approximate equilibrium grain size to be produced.

Structure and Properties of Tungsten Filaments After Use

Tungsten incandescent electric lamps are all so designed that when the lamps are used at rated voltage the temperature of the filaments will be above the recrystallization or equiaxing temperature of tungsten. This is especially true when the long time of heating of the filaments is considered. Since the operating temperatures of lamp filaments are in the grain growth region of tungsten (above the equiaxing temperature and below the melting point) and since the time of heating in this grain-growth range is long, sometimes exceeding 1500 hr., the structure of the filament will change during the life of the lamp. After a short burning, tungsten wires containing thoria will possess structures similar to that shown in Fig. 48. It will be noted that the grains are longer in the direction of the working than in a perpendicular direction. During the life of the lamp, this elongation is even more marked. Fig. 49 is a micrograph of a 40-watt tungsten filament after burnout. This filament contained thoria. It will be noted that the grains have been greatly elongated during the life of the lamp. These grains are equilibrium grains so far as deformational strains are concerned. The growth in a longitudinal direction has been more rapid than in an axial direction. The underlying causes for this type of grain formation have been studied, and the following conclusions have been reached:

The spherical thoria globules existing in the tungsten ingot before working are elongated during the working operations. They do not, however, elongate as much as the metallic grains. The drawn tungsten wire will consist of metallic fibers of tungsten elongated in the direction of working and non-metallic fibers or miniature rods of thoria parallel to the metallic tungsten fibers. When this wire is heated above its equiaxing temperature, the metallic fibers will change into very small equiaxed grains, but the thoria rods, if they change at all, only break up into rows of spheres, each row occupying the same general position as the thoria rod from which it was formed. Even the breaking up of the thoria into spheres takes considerable time. After the metallic grains of tungsten have broken up into very small equiaxed grains, these coalesce

with one another, forming fewer and larger grains. Grain growth will take place in accordance with the time, temperature, and resistance to grain growth. The resistance to grain growth in an axial direction will be much greater than in a longitudinal direction. In an axial direction, the thoria rods, or rows of thoria spheres, will present much more surface to resist grain growth than in a longitudinal direction, because the sides of the thoria rods will offer resistance to radial grain growth. Only the ends of the thoria rods, however, will offer resistance to grain growth in a longitudinal direction. By calculation, it can be shown that the resistance to grain growth in an axial direction due to the presence of thoria may be more than 50 times that in a longitudinal direction.

It will be seen later that the forced formation of the elongated grains in a tungsten filament makes it very much more rugged than it would have been had the grains been exactly equiaxed. Fig. 50 is a micrograph of one of the old squirted or pressed tungsten filaments after life test. This micrograph was kindly furnished by Mr. C. D. Young, of the Pennsylvania Railroad Co. It will be noted that the grains in this wire are equiaxed. This is the structure which renders tungsten extremely brittle and fragile at ordinary temperatures, whereas the structure shown in Fig. 49 renders tungsten rugged at room temperature. The reasons for this will be discussed later.

A great many different types of structure are encountered in tungsten filaments after they have been used for various lengths of time. Fig. 49 is a typical example.

The difference in resistance to grain growth between tungsten containing thoria and tungsten containing no thoria can be seen by referring to Fig. 51 and 52. Fig. 51 contains 0.75 per cent. thoria and Fig. 52 no thoria. Both wires have been heated for 10 min. to a temperature near 2850° C. These micrographs are of the natural surfaces of the wires. The boundary material of the grains volatilizes more rapidly than the crystalline material, so that the grain boundaries can be seen without etching.

If tungsten develops very coarse grains when used as a filament, it has the property of being much stiffer at high temperatures than when composed of fine grains. The wires will not sag due to their own weight even when heated to a temperature of about 2800° C. If the filament, however, is fine grained, it may sag badly due to its own weight. There is danger in producing coarse-grained structures, because if a boundary line between two grains cuts sharply across a section of the filament on a plane approximately perpendicular to its axis, one section of the filament may be displaced in a direction perpendicular to its axis, thus causing the phenomenon known as "offsetting." We now know that at the boundaries between two tungsten grains a film of amorphous tungsten exists (this assumes the validity of the amorphous theory) and that at

the temperatures at which the lamp filaments are used, this amorphous film is more or less fluid and weak mechanically. This is why the fine-grained tungsten wires are weaker at high temperatures than the coarse-grained tungsten. This is also the reason that offsetting takes place at the grain boundaries traversing the whole cross-section of the wire.

It is possible to form tungsten wires which are both coarse grained and substantially non-offsetting. Fig. 53 is a micrograph of a tungsten filament that is both coarse grained and non-offsetting. It can be noted that these grains are very long in a direction parallel to the axis of the wire, and that at no place does a grain boundary extend across the diameter of the wire in such a way that offsetting can take place.

Weldability of Tungsten

Many attempts have been made to weld the particles of tungsten together by working at a very high temperature. No headway has been made in this direction. To be workable, a piece of tungsten must be substantially non-porous—that is, the individual particles must have been previously welded together at a temperature near the melting point of tungsten in an atmosphere of hydrogen or other gas which is either helpful or at least not harmful to the tungsten.

Sometimes the swaged tungsten rod splits during the swaging operation. Attempts have been made to weld these split portions together by working at a high temperature. The highest temperature available was 1700–1800° C. It was not found possible to weld the tungsten in this manner. Tungsten can be welded electrically at temperatures near fusion.

Notes on Polishing, Mounting and Etching Tungsten

Tungsten is not an easy metal to polish. It is so resistant to the action of abrasion of the polishing powders that levigated alumina can be substituted for tripoli to advantage just preceding the rouge.

White cast iron has been used to advantage as a mounting material for small pieces of tungsten which cannot conveniently be handled without some sort of a mounting. The piece of tungsten to be mounted is put in a mold and the molten cast iron poured around it. The white cast iron and tungsten are so nearly the same hardness that flat surfaces can be produced on the tungsten during polishing. It is sometimes very difficult to mount and polish the smallest tungsten wires. This has been accomplished in a successful manner, however, on wires less than 0.001 in. in diameter. One satisfactory method is as follows: An ordinary malleable iron $\frac{3}{8}$ -in. (9.5-mm.) pipe cap is planed on the closed end outside. It is then drilled on the inside to a plane parallel to the outside plane. A round cover glass is put on the inside of the pipe cap, on which are placed

several pieces of the small tungsten wire to be polished. Another cover glass is placed on top of these wires, after which the opening of the pipe cap is filled with powdered glass. It is then put in a furnace, being maintained in an upright position, and heated for about 5 min. to a temperature of 800° or 900° C. It has been found in many experiments that this temperature does not affect the structure of tungsten wire. The pipe cap with contents is then removed from the furnace and the glass which has congealed is pressed tightly into the pipe cap and allowed to cool slowly. The metal portion on the end of the pipe cap is then turned off in a lathe and the glass is exposed. This glass containing the samples of tungsten is polished in the ordinary manner until the tungsten wires are exposed, and the polishing is completed in the ordinary manner.

Boiling hydrogen peroxide is used for etching most of the tungsten products. Tungsten may also be etched electrolytically with good results, using a solution of sodium hydrate for electrolyte.

Why is Fibrous Tungsten Ductile?

This question has been the subject of much work and much thought. The fact that fibrous tungsten is ductile has been known for 10 years, but no explanation has been forthcoming. The result could not have been predicted from metallurgical knowledge. The explanation has been worked out step by step. The researches which have finally resulted in an explanation also permit the postulation of some new metallographic laws relating to all metals. In making the explanation, the amorphous theory is considered valid. The explanation, however, does not depend upon the validity of the amorphous theory or any other theory; it depends on facts which have been experimentally ascertained. These researches may, in fact, be used to strengthen the amorphous theory.

Crystalline tungsten is somewhat malleable and ductile at room temperature—that is, if a single grain of tungsten can be isolated, it can be slightly deformed cold before rupturing. The cold deformation strain hardens the tungsten grain and makes it brittle, similar to this action in common ductile metals. Crystalline tungsten can also be deformed above room temperature; it is capable of more permanent deformation without becoming brittle, the higher the temperature at which the deformation is produced.

Amorphous tungsten is very brittle at room temperature. It is capable of being deformed without rupture at high temperature. Tungsten composed of small equiaxed grains is not ductile or malleable at room temperature. It may be both malleable and ductile at elevated temperatures. A fracture at room temperature shows that the break has taken place largely at the grain boundaries. Occasionally, along the fracture line, a grain is encountered which has been broken in two, but this will be

caused by a local high resistance to rupture along the grain boundaries. Fine-grained tungsten can be deformed under suitable conditions (such as are outlined previously) at high temperatures.

The reasons for fibrous tungsten being ductile cold can be stated briefly as follows: Tungsten composed of equiaxed grains is brittle at room temperature because the brittle amorphous phase at the grain boundaries permits rupture before a load sufficient to deform the malleable crystalline phase can be applied. Tungsten possessing this structure is brittle even though the crystalline material present is more capable of permanent deformation at room temperature than the crystalline portions of fibrous tungsten. Fibrous tungsten is ductile at room temperature (assuming that the fiber has been produced under proper conditions) in spite of the fact that it contains more of the amorphous phase than equiaxed tungsten. It is ductile because the grain distortion by working arranges the grain boundaries in such a manner that the resistance to rupture along them is so great that rupture is forced to take place through the deformed grains themselves. These grains, which will usually have been deformed above room temperature, will possess the ability to be further deformed at room temperature; rupture through them cannot take place without further deforming them, so the metal assumes ductility. The subject of deformation of metallic grains at a certain temperature and the increase of ductility by lowering the temperature will be treated later.

We must accept as a fact, which I have observed many times, that rupture along the amorphous planes in tungsten is much more pronounced along grain boundaries than along the amorphous slip planes in deformed tungsten grains. It is probable that the path of rupture along the amorphous slip planes in a deformed grain would be many times more intricate, involving intermeshings of submicroscopic size, than the path of rupture along the grain boundaries themselves. Whatever may be the explanation for this, we must accept it as fact. It should be kept in mind that only when the amorphous phase of the metal becomes very brittle does the fracture seek the grain boundaries. This condition obtains in tungsten at room temperature but not in the ordinary ductile metals.

Even a fibrous tungsten wire which is ductile is only malleable when the deforming pressure is applied at all points of its circumference at the same time, like the swaging die action. When one of these wires is placed on an anvil and struck with a hammer, it splits into many threads—that is, the deformed grains separate from each other.

Probably one of the major causes for rupture along the amorphous grain boundaries in tungsten, in preference to through the grains themselves, is the difference in coefficient of expansion of the amorphous and crystalline phases. Glass, a completely amorphous substance, can be

cracked by unequal heating or cooling, the cracks resulting from the different degrees of expansion or contraction of different parts of the piece. If we consider that fine-grained tungsten is made up of crystalline grains surrounded by films of amorphous tungsten, then these two phases will have different coefficients of thermal expansion. At the higher temperatures, these differences are easily adjusted because of the plasticity of the amorphous phase. At lower temperatures, however, both the amorphous and crystalline phases will be very rigid. This will force the strains of unequal expansion during heating or unequal contraction during cooling, into either the crystalline or amorphous material, or both. There are several reasons why these strains at low temperatures should be taken up largely by the amorphous phase. The amorphous phase is the only one possessing continuity. The crystalline phase consists of grains none of which actually touch each other. The continuity of the system depends on the amorphous phase. Any difference in coefficient of expansion between the amorphous and crystalline phases, no matter in what direction the difference may be, must affect therefore the amorphous phase. If internal strains are set up in this manner at the grain boundaries, smaller external loads will be required to cause rupture than would be indicated by the actual measure of cohesion of the isolated amorphous phase.

To obtain a somewhat better idea of these phenomena, let us consider the properties of tungsten wires about 0.007 in. (0.18 mm.) diameter with four types of structure.

1. *The Whole of the Wire Is Composed of a Single Grain.*—Since crystalline tungsten is somewhat malleable and ductile at room temperature, such a wire could be deformed cold. Cold deformation would strain-harden the tungsten and make it more brittle, and when continued far enough would break it because of the brittleness. The permanent deformation of the crystalline tungsten would generate amorphous tungsten at the planes of slip. The hardening and embrittling would be caused by the amorphous metal.

2. *The Tungsten Wire is Composed of Small Equiaxed Grains.*—Such a tungsten wire is brittle and fragile at room temperature. It cannot be appreciably bent (except the bending which takes place within its elastic limit) without breaking. The break will take place largely along the grain boundaries. These grain boundaries consist of thin films of tungsten in the brittle amorphous condition. The amorphous phase has in reality greater cohesion than the crystalline phase at room temperature, but it is under great internal stress due to the difference in coefficient of expansion between it and the crystalline phase.

3. *The Tungsten Wire Has a Fibrous Structure.*—To obtain a mental picture of this particular structure, suppose the ingot from which the wire was made was $\frac{1}{4}$ in. (6.35 mm.) square and contained 3800 gr. per square

millimeter. It is worked at temperatures below that of equiaxing so that the grains are progressively elongated from the beginning of working. When the wire is 0.007 in. diameter, the grains will have been changed into fibers the average length of which will be about 1 in. and the average diameter about 0.00002 in. The end of a given metallic fiber will usually not be contiguous to the ends of other fibers with which it is in contact. A tungsten wire with such a structure is ductile cold. It can be drawn cold, bent cold, coiled, etc. It will contain more amorphous tungsten than the fine-grained sample which was brittle. It will be ductile cold because the metal has a tendency to break along the amorphous planes at the grain boundaries and the path of rupture along these will be so great that the break is forced to take place through the crystalline material which, though not as malleable and ductile as the crystalline material before strain hardening, will still possess the properties of malleability and ductility to a certain extent at room temperature. A break through it, therefore, must cause a certain amount of deformation before rupture can take place, thus giving rise to the property of ductility.

4. *The Wire Consists of Elongated Grains Which Have Not Been Strain-hardened.*—Such a structure results from long heating of tungsten containing thoria or other non-metallic substances. The arrangement of the grains makes a long path for rupture along the grain boundaries, so a much greater load can be applied before rupture than when the metal is composed of equiaxed grains. This makes tungsten possessing an elongated grain structure stronger or more rugged than the equiaxed structure. At times, such wires even possess slight ductility at room temperature. Electric incandescent lamp filaments frequently possess these elongated grain structures and are as a consequence very rugged.

It is thus seen that the ductility of tungsten at room temperature does not depend on the quantity of amorphous tungsten, but on its arrangement. It has been stated before that the tensile strength of a tungsten ingot is about 18,000 lb. per square inch. Tungsten wire possessing a fibrous structure at 0.007 in. diameter will have a tensile strength of about 340,000 lb. per square inch. The actual cohesion is greater in the drawn tungsten wire than in the equiaxed ingot. The cohesion measured in each case is that of a system made up of what may be considered physically as two separate materials with different properties, but in the case of the equiaxed ingot the internal weakening strains predominate and in the case of the fibrous wire they are eliminated.

As an example of the action of the crystalline and amorphous phases in equiaxed and fibrous tungsten, let us suppose that a structure is made up of grains of iron which we will consider as analogous to the crystalline tungsten, the grains being bound together with very thin films of glass which we will consider analogous to the amorphous tungsten cement surrounding the grains. In the first example, let us suppose that the

grains of iron are equiaxed and unstrained—that is, similar to equiaxed tungsten. This structure will assume largely the properties of the brittle glass cement. If a grain of iron could be isolated, it would be malleable, but if the structure taken as a whole is hammered, it will fly to pieces, and if broken in tension, the breaking load will be too small to force any marked permanent deformation on the iron grains. This structure will be brittle. If, however, the structure were heated to a red heat, at which temperature both iron and glass are known to be workable, then considerable deformation could be effected by hammering or rolling. Let us suppose that such a structure could be rolled or drawn while hot until the dimensions of the deformed iron grains would be comparable to the dimensions of tungsten fiber. The glass film surrounding the grains of iron will remain intact. (In the actual working of the metal, it is very probable that the amorphous films surrounding the grains are made thicker by mechanical working.) Let us further suppose that in this amount of deformation the iron grains still possess some ductility in the cold. When cold ductility tests are made, it will be found that the glass films are no longer in a commanding position and the path of rupture will be forced largely through the deformed iron grains themselves. Such a structure with the same quantity of glass present will be ductile at room temperature. It has not been attempted to make the analogy perfect, because glass does not possess the same properties as amorphous tungsten, nor does iron possess the same properties as crystalline tungsten, and glass could not be generated within an iron grain during deformation.

That the fracture in tungsten tends to take place along the grain boundaries is shown conclusively in Fig. 55. This fracture was in a coarse-grained sample. One of the cracked boundary lines in Fig. 55 extends to the surface of the tungsten ingot, and the crack does also. In one place where the grain boundary line was rather jagged, the fracture took place through a portion of the crystalline material rather than at the grain boundary. The other cracked grain boundary abuts a fine-grained portion of the tungsten ingot at which the crack stops abruptly. This shows that resistance to rupture is less along a rather straight grain boundary than around the grain boundaries of fine-grained metal. Fig. 56 shows how the crack has jumped across the crystalline portion in preference to following the jagged grain boundary line. Fig. 57 shows the abrupt ending of a crack where the grain boundary line between two large grains intersects a fine-grained area, and Fig. 58 shows that the fracture of a fine-grained area follows in general the grain boundary line. There are two or three cracks in Fig. 42, and it can be plainly seen that these cracks follow the grain boundaries.

That rupture tends to take place along the boundaries of deformed grains in fibrous tungsten can be seen from Fig. 54. That the fracture

does not take place entirely along these grain boundaries is due to the fact that the resistance to rupture through the deformed grains or fibers is less in fibrous tungsten than along the deformed grain boundaries. If the deforming load is applied to fibrous tungsten longitudinally, the wire is ductile, but if applied transversely, it is brittle.

Some General Metallographic Propositions

The discussion in the preceding caption shows why fibrous tungsten is more ductile at room temperature than equiaxed tungsten. Another significant fact has been observed with tungsten, namely, that after the limit of ductility has been reached by working at, say, a red heat, the tungsten after cooling to room temperature or other lower temperatures becomes ductile at these temperatures. Experiments have been made which show that this phenomenon is common to all ductile metals. The reasons have been ascertained. The underlying reason for the loss of ductility by working a metal at a certain temperature below its annealing temperature and the regaining of ductility by cooling to some lower temperature, is that the amorphous phase of any metal will increase in cohesion on cooling, at a faster rate than the crystalline phase. Let us refer to Plate 3. This shows the general cohesion-temperature curves of the amorphous and crystalline phases of metals. The direction of the curves will have to be determined for any given metal, but the general relationship will be found similar to those given in Plate 3. The curve traced in by a continuous line represents the change in cohesion of the amorphous phase with change in temperature. The cohesion is substantially zero at the melting point of the metal and increases as the temperature decreases, reaching a maximum at absolute zero. The dotted curve represents the change in cohesion of the crystalline phase with change in temperature. The crystalline phase disappears and changes into the amorphous phase when the metal is melted. On cooling from above the melting point, the crystalline phase forms during solidification and immediately at the melting temperature its cohesion assumes a finite value many times greater than that of the amorphous phase at the same temperature. On cooling below the melting point, however, the crystalline phase increases in cohesion at a very much slower rate than the amorphous phase. At some temperature between the melting point and absolute zero (in most metals not far from 0.35 to 0.45 of the absolute melting point) the cohesion of the crystalline phase will be the same as that of the amorphous phase. This temperature I have called the "equi-cohesive temperature."³⁴ It corresponds in most, if not all, metals, to the lowest equiaxing temperature of the severely cold-worked metal. Just as the equiaxing temperature of the metal is increased with decrease in the time of heating, the apparent equi-cohesive temperature increases as the

time of applying the load by which the cohesion is measured is decreased. If a metal is deformed above the equi-cohesive temperature and kept at that temperature, the grains will not remain permanently deformed, but will equiax; the properties of the metal will be different after equiaxing. If, however, the grains are deformed below the equi-cohesive temperature, they will remain permanently distorted. Below the equi-cohesive

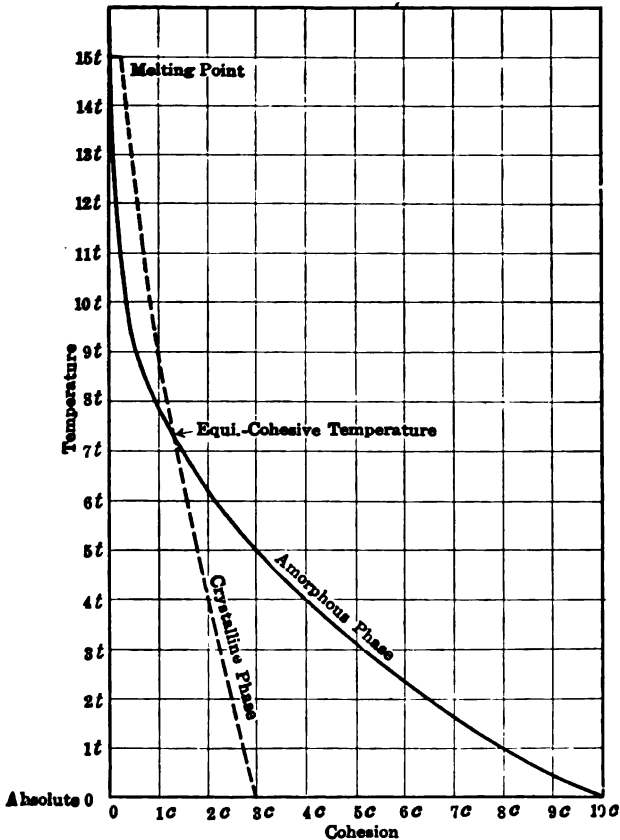


PLATE 3.—COHESION-TEMPERATURE CURVES OF AMORPHOUS AND CRYSTALLINE PHASES OF ANY METAL.

temperature, the amorphous phase has not only greater cohesion than the crystalline phase but its cohesion increases much faster with decrease in temperature.

Let us suppose that Plate 3 represents the cohesion-temperature curves of tungsten and that the temperature of wire drawing is $4t^{\circ}$. The crystalline phase at this temperature has a cohesion of $2c$ and the amorphous phase $4c$. The wire drawing can be continued until the load necessary to break the wire at a temperature of $4t^{\circ}$ is not sufficient to

further deform the crystalline phase. Before any deformation has taken place at $4t^\circ$ the crystalline phase will have a cohesion of $2c$, but as the deformation continues amorphous metal will be generated at the planes of slip, and these being in a commanding position will increase the apparent cohesion of the deformed grain. Now let us suppose that room temperature corresponds to $1t^\circ$. The cohesion of the crystalline phase at this temperature is $2.7c$ and that of the amorphous phase is $8.1c$. It will be noted that the amorphous phase at room temperature is $5.2c$ more cohesive than the crystalline phase, whereas at $4t^\circ$ it is only $2c$ more cohesive. The limit of ductility at $4t^\circ$ was governed to a certain extent by the difference in cohesion between the amorphous and crystalline phases. By cooling to room temperature this difference has increased $3.2c$. If now the metal is subjected to a ductility test at room temperature, a load sufficient to further deform the crystalline phase can be applied before rupture takes place; in other words, the metal is ductile and it has gained ductility because the amorphous phase increases in cohesion with decrease in temperature at a faster rate than the crystalline phase.

One point must not be confused. The limit of ductility of a metal at a certain temperature does not mean that the crystalline phase has been deformed to the greatest possible extent at that temperature. It simply indicates that the load necessary to further deform the crystalline phase cannot be applied to the metal by tension without breaking it. Even though it takes a greater load to deform the crystalline phase at a lower temperature, the increased load which can be applied by tension before rupture takes place (depending largely upon the cohesion of the amorphous phase) will be much more than the increase in the cohesion of the crystalline phase. Much more deformation can be forced on a given metal at a temperature below that of equiaxing by application of pressure than by tension. Rupturing of metals by pressure, however, must be considered as a natural modification of rupture by tension. A metal, for example, can be subjected to the highest hydrostatic pressures now available without permanently deforming it in the least. Pressure alone, therefore, will not change the external shape of a metal—that is, it will not permanently deform it. Deformation by pressure, therefore, implies a difference in pressure between two parts greater in magnitude than the cohesion of the metal to be deformed. In some cases, during the application of pressure to a metal, certain parts are actually in a state of tension and may break because of it. In other cases all parts of the metal may be subjected to pressure but certain parts will receive enough more pressure than other parts to cause permanent deformation. By utilization of the property of malleability, a metal may be deformed to a greater extent than by the utilization of ductility.

It is doubtful whether the actual limit of deformation of any crystalline metal has ever been reached experimentally. The temporary limit of deformation is always reached when the load necessary to cause it also causes the metal to rupture.

Beilby's observations on copper, gold, and silver fit in with these ideas very nicely. A description of his experiments are here given in his own words:* "Gold, silver and copper of the highest purity were the metals used. The diameters of the wires at all stages were carefully measured by a micrometer screw gage. The increases of length by wire drawing were also measured. After a final annealing, wires were drawn to as much as fourteen times their original length. Their tenacity was determined by applying a water load to the vertically hung wire. As stated above, the maximum tenacity was reached in wires drawn from three to five times their original length. A hard-drawn wire shows no general extension even under the breaking load. The broken pieces when brought together show that the small local extension which occurs at the point of rupture may amount to 1 per cent., or less, but it is purely local as proved not only by the absence of any general stretching, but also by a full series of measurements of the diameter at many points along the length. The tenacity was always calculated on the average cross-sections worked out from these measurements. After a large number of experiments had been made at the ordinary temperature, it was decided to repeat these at the temperature of liquid air or -182° . The results showed that at this low temperature the tenacity of these metals is very much increased, gold rising from 15.6 tons per square inch at 15° to 22.4 tons at -182° , silver from 25.7 tons at 15° to 34.4 tons at -182° , and copper from 28.4 tons at 15° to 36 tons at -182° . The most unexpected result was that all the hard-drawn wires stretched 11 to 12 per cent. at the lower temperature before breaking. The plasticity which had disappeared at 15° reappeared at the lower temperature. Our conclusion at the time was that the restarting of plasticity at the low temperature was due to the general increase of tenacity which enabled the wire better to resist the disruptive strains in the die."

Our discussions show that the mere increase in tenacity cannot be responsible for the ductility which Beilby observed. For example, Hadfield³⁸ found that the ductility of iron decreased with increased tenacity as the temperature was lowered to that of liquid air. What happened in Beilby's experiments was that the tenacity increased faster with decrease in temperature than the cohesion of the crystalline phase due to the differential cohesion between it and the amorphous phase. In Plate 3, let us suppose that room temperature corresponds to $3t^{\circ}$ and liquid air temperature to $1t^{\circ}$ and the curves as given represent in general the prop-

* *Journal of the Institute of Metals* (No. 2, 1911), 6, 19.

erties of the crystalline and amorphous phases of the metals with which Beilby experimented. At room temperature the cohesion of the crystalline phase is 2.2c, and of the amorphous phase 5.1c, while at 1t° the cohesions are 2.7c and 8.1c respectively. Beilby had cold-drawn the wires at room temperature till they were brittle. On cooling to -182° (1t°), the ratio between the cohesion of the amorphous and crystalline phases had greatly increased so that at 1t° tensile load could be applied before the metals ruptured sufficiently to further deform the crystalline phase.

It will be evident, from what has been said, that the metals might be wire drawn at 1t° till they became brittle at that temperature and they would then become ductile if cooled to a temperature of, say, $\frac{1}{2}$ 1t°.

A further experiment with a wire of aluminum copper alloy also fits in nicely with these fundamental ideas. The wire was worked cold at room temperature until it would break when bent through an angle of about 60°. A piece of wire was then immersed in liquid air and was bent double and straightened again without cracking.

Further confirming evidence is at hand and a rather complete set of experiments dealing with these general problems has now been completed and will be reported in a separate paper. The hypothesis has been sufficiently verified so that results can be predicted from it.

I have considered the application of this hypothesis to substantially pure metals and solid solutions. The application to other classes will be more complicated. Let us take steel as an example. The cohesion-temperature curves of pure iron have jogs in the crystalline curve corresponding to the allotropic points. The approximate curves for iron as well as for cementite would have to be ascertained. In annealed steel, at least three physically different substances will be present; namely, crystalline ferrite, crystalline cementite and the amorphous solution of iron and iron carbide. After cold deformation there may be five physically different constituents present; namely, crystalline ferrite, amorphous iron, crystalline cementite, amorphous cementite and the amorphous solution of iron and cementite. By knowledge of the properties of each of these constituents and their structural positions in the steel, predictions may be made regarding the physical properties of the piece of steel taken as a whole.

It should be pointed out that the metals which have the greatest possibilities for improvement by mechanical working, or those metals which should ultimately have high tensile strength whether coupled with ductility or not, should (a) possess high unit cohesion in both the crystalline and amorphous phases, and (b) the cohesion of the latter should be much greater than that of the former at room temperature. Such metals will have relatively high equi-cohesive temperatures.

In fibrous tungsten, a condition is obtained which makes the ductility

greater at room temperature than that of the equiaxed tungsten. The general hypothesis of increase in ductility in metals already possessing fibrous structures by decreasing the temperatures is entirely independent of the relative ductility of the fibrous and equiaxed structures. In Beilby's experiments quoted above, for example, the ductility at -182° of the metals with fibrous structures may not have been as great as that of the equiaxed metals at the same temperature. With most, if not all, metals, however, some low temperature will be reached at which the metals in the equiaxed condition will be brittle and the same metals possessing fibrous structures which will have been produced at some higher temperature will be ductile. Iron, for example, possesses these properties at the temperature of liquid air, and tungsten and molybdenum, at ordinary or room temperature.

The amorphous phase of iron is supposed to be brittle at room temperature. It is not sufficiently brittle to cause rupture along the grain boundaries at room temperature. Liquid air temperature, however, will cause coarse-grained iron to fracture along the grain boundaries. A metal with an equiaxed grain structure cannot be very ductile at high temperature because the amorphous phase is weaker than the crystalline. Its ductility (assuming one of the ductile metals) increases on cooling to a certain point, below which it begins to become less ductile. The temperature may be lowered sufficiently to make it brittle.

Experimental proof has also been obtained showing that if a metal is worked at a certain temperature below its annealing temperature, till it becomes brittle at that temperature, it is more brittle at higher temperatures below that of annealing.

ACKNOWLEDGMENTS

I wish to express my indebtedness to B. L. Benbow, Manager of the Cleveland Wire Division of the General Electric Co., who instigated the work on the metallography of tungsten and under whose direction the work was carried out. I wish also to thank Messrs. L. Cover, L. S. Twomey, E. J. Hull, W. T. Burgoon, and W. P. Sykes, for valuable aid in carrying out the experiments.

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FIG. 1.—TUNGSTEN INGOT. $\times 152$.



FIG. 2.—SWAGED TUNGSTEN ROD,
0.214 IN. DIAM. $\times 152$.



FIG. 3.—SWAGED TUNGSTEN ROD, 0.125 IN. DIAM. $\times 152$.



FIG. 4.—SWAGED TUNGSTEN ROD,
0.082 IN. DIAM. $\times 152$.



FIG. 5.—SWAGED TUNGSTEN ROD,
0.030 IN. DIAM. $\times 152$.

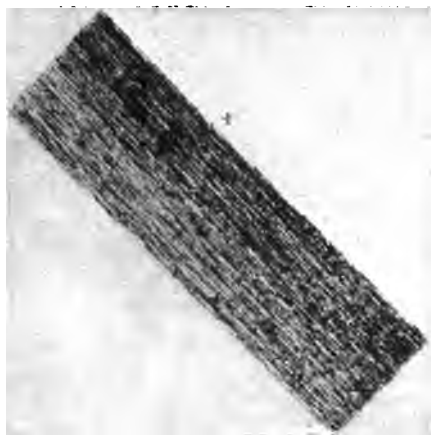


FIG. 6.—DRAWN TUNGSTEN WIRE, 0.010 IN. DIAM. $\times 169$.

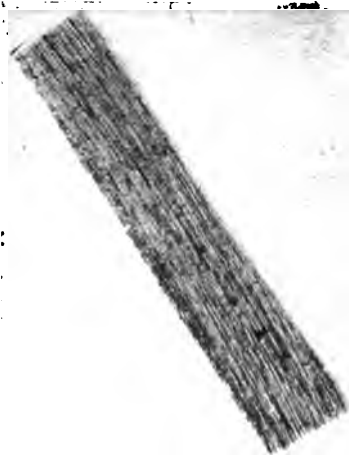


FIG. 7.—DRAWN TANTALUM WIRE, 0.007 IN. DIAM. $\times 125$.



FIG. 8.—TANTALUM WIRE ANNEALED 5 MIN. AT 1600°C . IN VACUUM. $\times 125$.



FIG. 9.—TANTALUM WIRE ANNEALED 1 MIN. IN HYDROGEN ATMOSPHERE. $\times 125$.



FIG. 10.—CONTAINING
1 PER CENT. ThO_2 .



FIG. 11.—CONTAINING
2 PER CENT. ThO_2 .



FIG. 12.—CONTAINING
3 PER CENT. ThO_2 .



FIG. 13.—CONTAINING
4 PER CENT. ThO_2 .

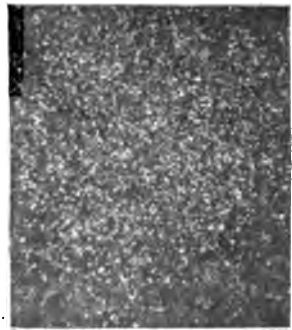


FIG. 14.—CONTAINING
5 PER CENT. ThO_2 .

FIG. 10 TO 14.—TUNGSTEN INGOTS HEATED 12 MIN. AT 3200°C . $\times 16$.

FIG. 15.—CONTAINING 1 PER CENT. ThO_2 .FIG. 16.—CONTAINING 2 PER CENT. ThO_2 .FIG. 17.—CONTAINING 3 PER CENT. ThO_2 .FIG. 18.—CONTAINING 4 PER CENT. ThO_2 .FIG. 19.—CONTAINING 5 PER CENT. ThO_2 .

FIG. 15 TO 19.—TUNGSTEN INGOTS HEATED 12 MIN. AT 3200°C . $\times 389$.



FIG. 20.—TUNGSTEN INGOT SHOWING 2 LARGE GRAINS IN POSITION TO ABSORB SMALL GRAINS. $\times 117$.



FIG. 21.



FIG. 22.



FIG. 23.

FIG. 21.—TRANSVERSE FRACTURE OF TUNGSTEN INGOT CONTAINING 0.75 PER CENT. ThO_2 , HEATED 20 MIN. AT 2600°C . $\times 5$.

FIG. 22.—TRANSVERSE FRACTURE OF TUNGSTEN INGOT CONTAINING 0.75 PER CENT. ThO_2 , HEATED 30 MIN. AT 2600°C . $\times 5$.

FIG. 23.—TRANSVERSE FRACTURE OF TUNGSTEN INGOT CONTAINING 0.75 PER CENT. ThO_2 , HEATED QUICKLY TO 3200°C . AND HELD FOR 30 MIN. $\times 5$.



FIG. 24.—TUNGSTEN INGOT CONTAINING 0.75 PER CENT. ThO_2 , HEATED 20 MIN. AT 2600°C . TRANSVERSE SECTION. $\times 9$.

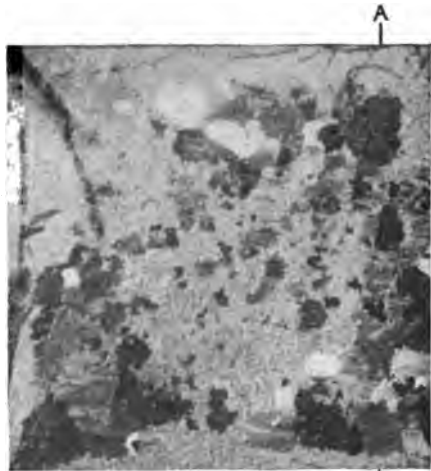


FIG. 25.—TUNGSTEN INGOT CONTAINING 0.75 PER CENT. ThO_2 , HEATED 30 MIN. AT 2600°C . TRANSVERSE SECTION. $\times 9$.

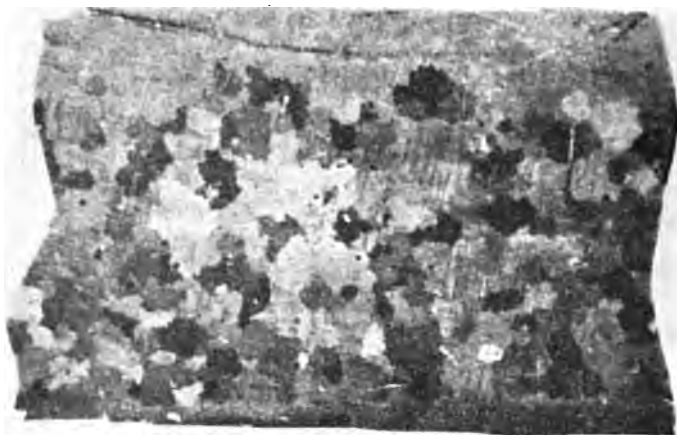


FIG. 26.—LONGITUDINAL SECTION AT SECTION A-A OF FIG. 25. $\times 9$.



FIG. 27.

FIG. 27.—LONGITUDINAL FRACTURE OF TUNGSTEN INGOT CONTAINING 0.75 PER CENT. ThO_2 . COLD END IN ELECTRODE CLAMP. $\times 5$.



FIG. 28.

FIG. 28.—TUNGSTEN INGOT CONTAINING 0.75 PER CENT. ThO_2 , HEATED QUICKLY TO 3200°C . AND HELD 30 MIN. $\times 5$.

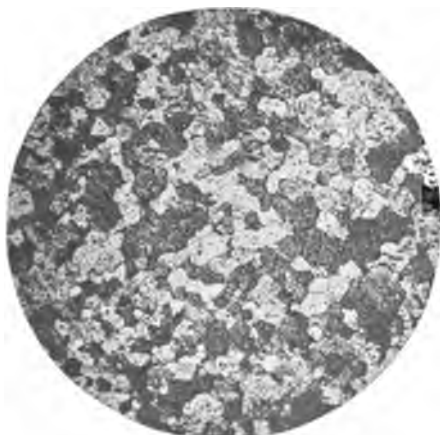


FIG. 28a.—TUNGSTEN INGOT CONTAINING 0.75 PER CENT. ThO_2 , HEATED QUICKLY TO 3200°C . AND HELD 30 MIN. $\times 144$.

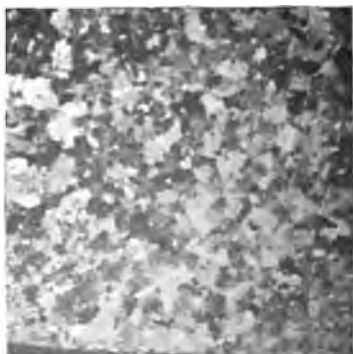


FIG. 29.—TUNGSTEN INGOT CONTAINING 0.75 PER CENT. ThO_2 , HEATED 20 MIN. AT 2600°C . AND THEN HEATED 10 MIN. AT 3200°C . $\times 7$.



FIG. 29a.—TUNGSTEN INGOT CONTAINING 0.75 PER CENT. ThO_2 , HEATED 20 MIN. AT 2600°C . AND THEN HEATED 10 MIN. AT 3200°C . $\times 74$.



FIG. 30.—FINE-GRAINED TUNGSTEN INGOT WITH FUSED CENTER. $\times 15$.



FIG. 30a.—FINE-GRAINED TUNGSTEN INGOT WITH FUSED CENTER. $\times 144$.



FIG. 31.—COARSE-GRAINED TUNGSTEN INGOT WITH FUSED CENTER. $\times 17$.



FIG. 32.—INGOT WITH TUNGSTEN-CARBIDE NETWORK SURROUNDING TUNGSTEN GRAINS. $\times 950$.



FIG. 33.—a. TUNGSTEN INGOT CONTAINING BOTH ThO_2 AND CARBON. b. TUNGSTEN INGOT CONTAINING ONLY ThO_2 .



FIG. 34.—TUNGSTEN ROD CARBONIZED WITH CO. LIGHT PORTION IS TUNGSTEN CARBIDE. $\times 940$.



FIG. 35.—TUNGSTEN ROD CARBONIZED WITH HYDROCARBONS. LIGHT PORTION IS TUNGSTEN CARBIDE. $\times 400$.

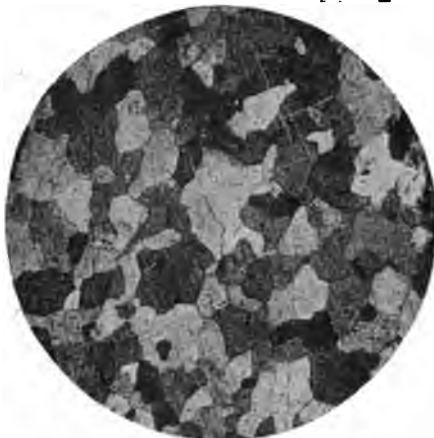


FIG. 36.—FINE-GRAINED TUNGSTEN INGOT, SWAGED AND RECRYSTALLIZED. $\times 74$.



FIG. 37.—COARSE-GRAINED TUNGSTEN INGOT, SWAGED AND RECRYSTALLIZED. $\times 74$.



FIG. 38.—STRUCTURE OF SWAGED TUNGSTEN ROD, 0.80 IN. DIAM. $\times 240$.

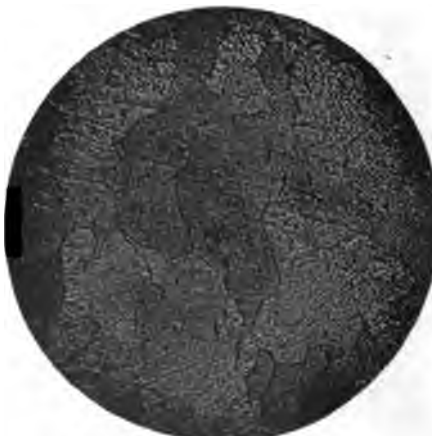


FIG. 39.—SWAGED TUNGSTEN ROD CONTAINING 0.75 PER CENT. ThO_2 , 0.080 IN. DIAM. RECRYSTALLIZED BY HEATING 3 MIN. AT 3100°C . $\times 240$.



FIG. 40.—SWAGED TUNGSTEN ROD CONTAINING NO ThO_2 . 0.080 IN. DIAM. HEATED BY ELECTRIC CURRENT SLOWLY TO 3100°C . $\times 73$.



FIG. 41.—SWAGED TUNGSTEN ROD, 0.080 IN. DIAM., CONTAINING NO ThO_2 . HEATED BY ELECTRIC CURRENT QUICKLY TO 3100°C . $\times 73$.

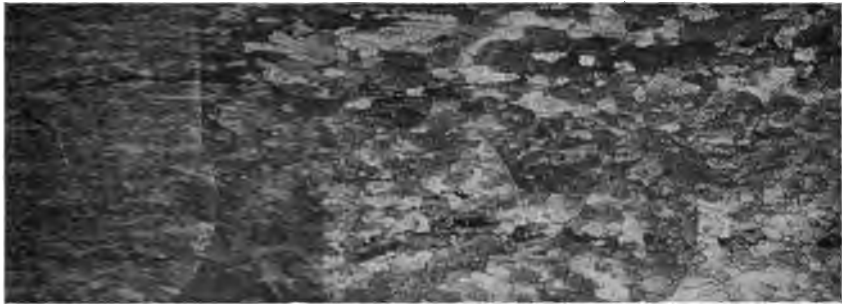


FIG. 42.—SWAGED TUNGSTEN ROD, 0.080 IN. DIAM., CONTAINING NO ThO_2 . HEATED BY ELECTRIC CURRENT 2 HR. AT 3000°C . END NEAR COLD ELECTRODE CLAMP. $\times 33$.



FIG. 43.—SWAGED TUNGSTEN ROD, 0.080 IN. DIAM., CONTAINING 0.75 PER CENT. ThO_2 . HEATED $9\frac{1}{4}$ HR. AT 3000°C . COLD END NEAR ELECTRODE CLAMP. $\times 155$.



FIG. 44.—SAME ROD AS FIG. 43, IN HOTTER REGION. $\times 155$.



FIG. 49.—TUNGSTEN FILAMENT 0.0015 IN. DIAM., CONTAINING 0.75 PER CENT. ThO_2 , AFTER BURN-OUT IN 40-WATT VACUUM LAMP. LONGITUDINAL SECTION. $\times 346$.



FIG. 45.—TUNGSTEN WIRE, 0.003 IN. DIAM., CONTAINING NO ThO_2 , HEATED BY ELECTRIC CURRENT QUICKLY ABOVE GERMINATIVE TEMPERATURE. $\times 355$.



FIG. 46.—SAME WIRE AS FIG. 45. HEATED BY ELECTRIC CURRENT SLOWLY THROUGH GERMINATIVE TEMPERATURE RANGE. $\times 355$.

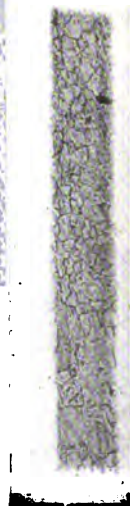


FIG. 48.—TUNGSTEN WIRE, 0.007 IN. DIAM., CONTAINING 0.75 PER CENT. ThO_2 , RECRYSTALLIZED BY SHORT HEATING AT ABOUT 2000°C . $\times 130$.

FIG. 47 ON NEXT PAGE.

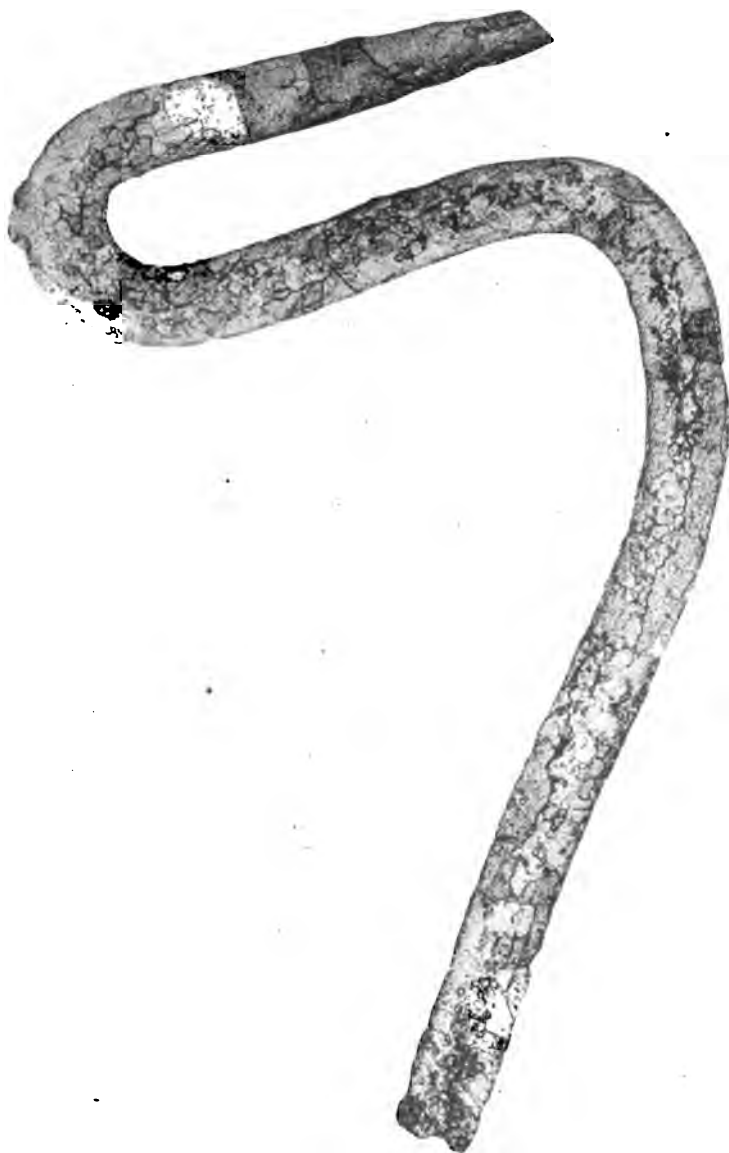


FIG. 47.—MOLYBDENUM HOOK USED AS FILAMENT SUPPORT IN 1000-WATT GAS-FILLED LAMP. LONGITUDINAL SECTION. $\times 104$.



FIG. 50.

FIG. 50.—OLD TYPE "SQUIRTED" TUNGSTEN FILAMENT AFTER BURN-OUT IN VACUUM LAMP. (YOUNG.) $\times 325$.

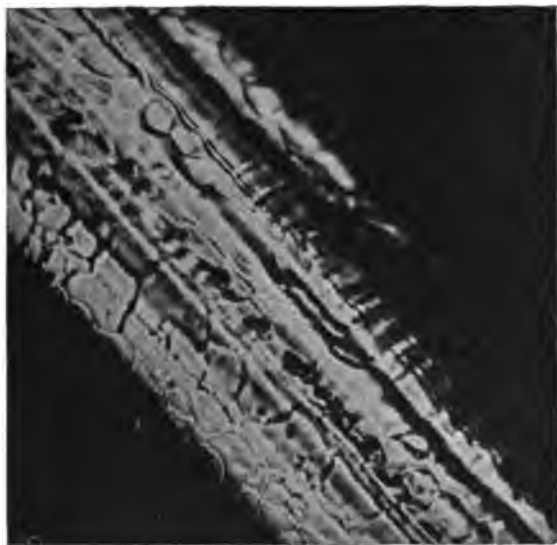


FIG. 51.

FIG. 51.—TUNGSTEN WIRE, 0.0036 IN. DIAM., CONTAINING 0.75 PER CENT. ThO_2 AFTER 10 MIN. EXPOSURE AT 2900°C . NATURAL SURFACE. $\times 480$.



FIG. 52.

FIG. 52.—TUNGSTEN WIRE, 0.0036 IN. DIAM., CONTAINING NO ThO_2 AFTER 10 MIN. EXPOSURE AT 2900°C . NATURAL SURFACE. $\times 480$.



FIG. 53.—TUNGSTEN WIRE, 0.007 IN. DIAM., CONTAINING NO ThO_2 . USED AS FILAMENT IN VACUUM LAMP, AFTER 66 HR. BURNING. SHOWS BOTH LARGE GRAINS AND ABSENCE OF GRAIN BOUNDARIES EXTENDING ACROSS WHOLE SECTION OF WIRE. $\times 60$

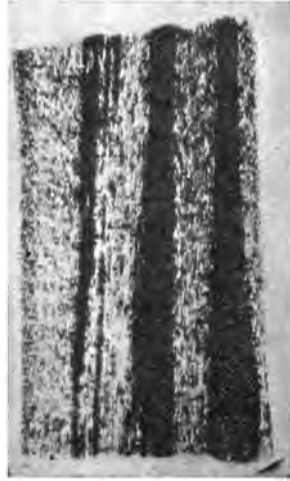


FIG. 54.—SPLIT TUNGSTEN WIRE CAUSED BY "OVERWORKING" OR WORKING TOO COLD. $\times 170$.



FIG. 55.—CRACKS AT GRAIN BOUNDARIES
IN TUNGSTEN INGOT. $\times 17$.

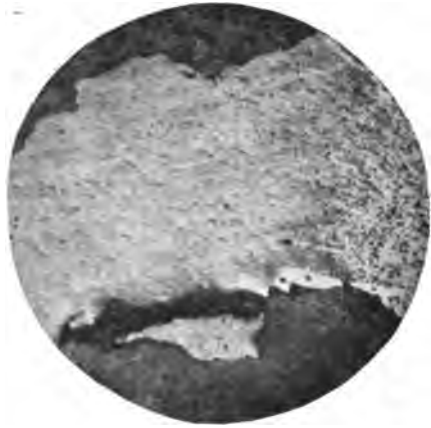


FIG. 56.—CRACK PARTLY THROUGH GRAIN
IN TUNGSTEN INGOT. $\times 50$.



FIG. 57.—CRACK BETWEEN TWO
GRAINS IN TUNGSTEN INGOT. STOPS AT
JUNCTION BETWEEN COARSE- AND FINE-
GRAINED REGIONS. $\times 61$.

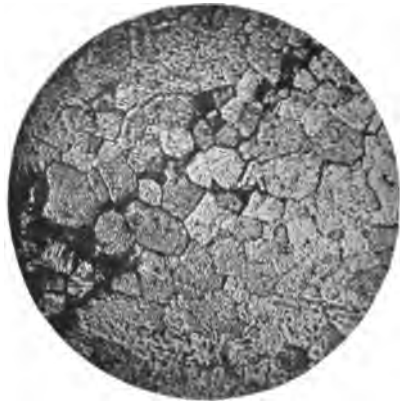


FIG. 58.—SHOWS CRACK ALONG
GRAIN BOUNDARIES IN FINE-GRAINED
TUNGSTEN INGOT. $\times 144$.

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Engineering Problems Encountered During Recent Mine Fire at Utah-Apex Mine, Bingham Canyon, Utah*

BY V. S. ROOD,† B. S., AND J. A. NORDEN,‡ BINGHAM CANYON, UTAH
(Colorado Meeting, September, 1918)

UNDERGROUND CONDITIONS BEFORE THE FIRE

Typical System of Workings

The general system of workings at the Utah-Apex is similar to that found in many of the western metalliferous mines. There is a vertical three-compartment shaft extending to the surface, from which the various levels have been driven to the orebodies. The 1000-ft. (305-m.) level, about $\frac{3}{4}$ mile long, was driven as a haulage and drain adit.

Geology

The formation is a flat north-dipping series of alternating limestone and quartzite beds. Extensive north-south faulting and fissuring have taken place, resulting in the formation of large replacement orebodies in the crushed zones in the limestone. The orebodies are irregular in shape and size, but follow closely the trend of the mineralizing fissures. The ore consists of galena, pyrite, sphalerite and small values in silver and gold. Large masses of non-commercial pyrite are frequently found in or adjacent to the orebodies, and more or less pyrite is found for some distance in the walls of the orebodies. Lenticular bodies of a black pyritic shale also occur in the zones where extensive faulting has taken place.

Mining Methods and Condition of Workings

Geological conditions, mentioned before, have made the ground extremely heavy. In mining above the 1000-ft. level, square-set and filling methods were used, but not altogether successfully. The

* Presented before the Utah Section, April 4, 1918.

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‡ Asst. Supt., Utah-Apex Mining Co.

crushing of timbers extended even into the filled portions of the stopes. The filling material itself, consisting of limestone, shale, and pyrite, possessed swelling qualities which added to the difficulty of maintaining chutes and manways. The oxidation of the filling absorbed much oxygen and produced considerable heat, making artificial ventilation necessary in the stopes. Plans had been made to adopt the slicing system on these orebodies above the 900-ft. level, but they did not extend far enough in this direction to make the proposed change advisable, and, thereafter, work was devoted solely to following the downward extension of the bodies.

The slicing system was adopted when work was started on the 1150-ft. (350-m.) level. In this system, raises are driven at short intervals

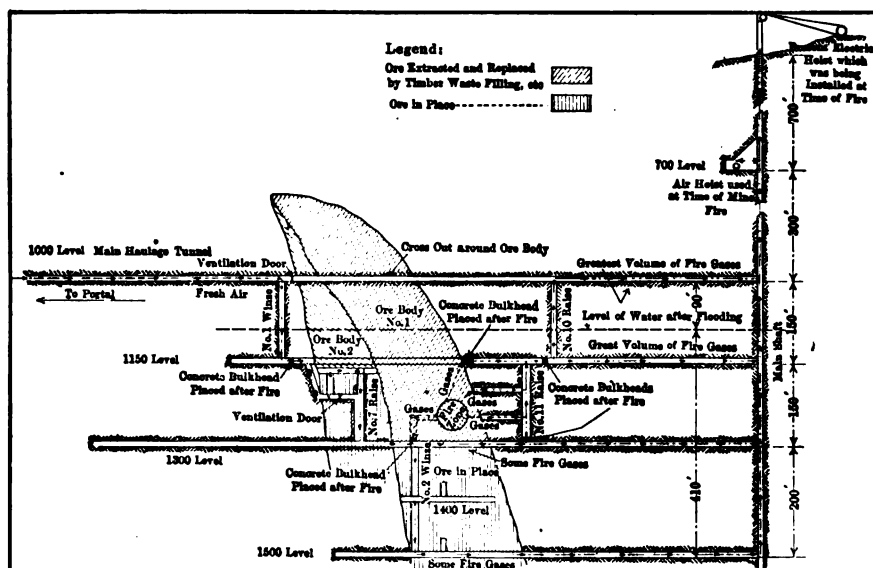


FIG. 1.—CROSS-SECTION THROUGH WORKINGS IN VICINITY OF FIRE ZONE.

through the ore to the level above and then beginning at the top, horizontal slices, 10 ft. (3 m.) thick, are taken across the body, the roof being allowed to settle as soon as the slice has been completed. The system was successfully applied. The mat of timber and caved material absorbed some oxygen, producing heat, but as it became firmly packed soon after each successive drop, the amount of circulating air through the mat was materially reduced, and ventilation easily maintained by the exhaust air from the drills with compressed air and slight blowing between shifts. The raises through the ore gave little trouble, and it was found to be an easy matter to keep one slice open until the ore had been mined. The saving in timber over former methods was marked;

little or no ore was lost through caving, and accidents from falling rock were practically eliminated.

At the point where the orebody was first encountered on the 1300-ft. level, its width was much less than on the level above. Ore was urgently needed to keep up normal production, and, as the walls looked firm, it was decided to try again the square-set stoping and filling methods. Stoping operations had not proceeded far before it became evident that work had been started on a faulted portion of the orebody. Filling drifts, driven in the walls of the stope, encountered other portions. Stoping was carried on, however, with results similar to those obtained in previous work above the 1000-ft. level. Raises were driven through the ore to the 1150-ft. level for ventilation. The free circulation of air caused the filling to become hotter than ever before. Temperatures of 98° F. were obtained in the working places where the current of air was good. Temperatures in the closely packed fillings were not obtained, but they were probably higher. While this stoping was in progress, it was decided that the other portions of the orebody should be mined by the slicing system. Raises marked No. 7 and No. 11 were then driven between the main levels, with sub-levels extending to the orebodies. While this work was under way, the original stope was finished, and the timbers soon crushed so that further inspection was impossible.

Mining went ahead in the new stopes off the raises, under the slicing system, and the block of ore adjacent to No. 11 raise was quickly finished, but not without considerable difficulty. The slices in these stopes continually broke through to the old stope, exposing the hot filling, which gave off so much heat that the slice had to be abandoned and the next one started. When the stopes were finished, the raise and sub-levels were left open, and a current of hot steamy air continued to pass out onto the 1150-ft. level. This condition caused no inconvenience or alarm, as all the old stopes gave off more or less steam and foul air. The last work was done at this point late in the fall of 1916, and no further attention was paid to the place. The stopes in the vicinity of No. 7 raise were extended successfully and with little heat, as they were separated from the other stopes by 50 ft. (15 m.) of waste rock. Early in 1917, the orebody was picked up on the 1500-ft. level, and in March raises had been started to block it out for stoping. Ventilation of the lower levels at this time was effected by natural air currents controlled by doors, which were kept closed on the 1000 and 1150-ft. levels, causing the current of air to pass to the lower levels and thence up the main shaft to the surface.

Discovery of the Fire

During the latter part of March, 1917, a strange odor was noticed in the air coming up No. 11 raise. For several days no attention was paid

to the matter, and then it was noted that the odor was becoming stronger. This tainted air came up to the 1000-ft. level through No. 10 raise, then flowed along this level and up the shaft. At this time the main hoisting engine was on the 700-ft. level, and the auxiliary or sinking hoist was on the 1000-ft. level. The engineers on the hoists, and the station tenders, began to complain that the bad odor was making them sick.

The master mechanic had spent many years in Butte, and from the first he maintained that the mine was on fire. On the afternoon of Mar. 26, the men who had worked in the foul air all day came off shift unmistakably sick, and it was evident that something was seriously wrong. The Yampa, a neighboring mine, had had considerable trouble from a mine fire. The foreman of this mine was taken underground, and he at once expressed the opinion that the mine was on fire.

CONDITIONS DURING THE FIRE

Selection of Fire-fighting Methods

The position of the fire zone was known only approximately. It was near the sub-levels, extending from No. 11 raise, in a caved and tightly filled gob, and therefore inaccessible. To reach the fire by attempting to drive through the caved stope might have taken a long time, and the fire would have spread rapidly. It was possible that the fire zone would be so large by that time that one heading would open only a small part of the zone. It seemed unlikely that direct fighting with a hose would be feasible, even if the fire were reached, and there would be a constant risk of life on the part of the men engaged in the work.

Confining the fire zone by placing concrete bulkheads at all openings to the old workings was considered. Such a plan meant turning over to the ravages of fire a space from which 500,000 tons of ore had been mined and in which several million feet of timber had been used. It would have been necessary to abandon about 100,000 tons of reserves. Much exploration work was in progress at that time on the 1150 and 1300-ft. levels, and was giving encouraging indications that new ore-bodies would be found on these levels along the same general ore-bearing channel which contained the old orebody. It seemed probable that the fire would spread throughout this channel in a short time, and make it necessary to confine future operations solely to shaft sinking and exploration below the 1500-ft. level, a long and expensive undertaking, with assured loss of profit while the work was being done. In this connection, the probable course of the fire was considered. In a fire in a building, the trend is usually upward or following the path of the gases generated; in fires underground, where the exit of gases is confined, the trend is invariably downward or toward the supply of fresh air. Under these conditions, it was by no means improbable that the downward

rate of burning would keep pace with stoping operations, or perhaps exceed them, in which case large amounts of ore would have to be abandoned from time to time. Furthermore, a confined fire is a constant menace to the lives of the miners working in other parts of the mine, and there is constant expense for watching, repairing and building new bulkheads. All operations are placed on an uncertain basis, as there is no knowledge of the time or place at which the fire will get beyond the confining bulkheads and cause a complete shut-down.

Confining a fire may be practicable in a mine having many and widely separated orebodies or in places where flooding is impossible, but the ultimate cost of such a method of control or the amount of ore in danger cannot be estimated with any degree of certainty until the system has been tried for several years. In the case of a new fire, it appears that every plan for the extinguishment of the fire should be considered before resorting to confining methods.

Had the fire started above the 1000-ft. level, or in some other place having no outlet at the top, flooding would probably have been out of the question, because an air pocket would have been formed and water prevented from reaching the fire. Had the fire been burning for a considerable time, there would have been the possibility of local air pockets in the edges of the stope. The smoke seemed to be derived entirely from the combustion of wood, which indicated with a fair degree of certainty that the fire was somewhere in the caved timbering and that by prompt flooding it could be extinguished, as the caved stope and filling would permit almost complete saturation.

It seemed certain that flooding would do little damage. The shaft and levels were in hard rock, and the timbered portions of the levels near the orebodies were in good condition. No stoping had been started below the 1300-ft. level. Above the 1300-ft. level there were several top-slicing stopes near No. 7 raise. One slice was open in these stopes, and therefore, at the worst, only this one floor could close up, and all ore remaining upon it could be obtained from the next slice below upon resumption of operations. Main drifts and raises in the orebody were closely lagged, and there appeared little likelihood of serious caving occurring at these points. The workings were lower than those of the neighboring mines and were separated from them by such distances that it appeared certain the mine would be water-tight and that flooding could be accomplished rapidly with the 600 or 700 gal. (2271 or 2649 l.) per minute available. It was estimated that 15,000,000 gal. would be required to fill the mine to the 1100-ft. level, and that the time consumed would be from two to three weeks. It was believed that if the new hoist which had been installed during the winter were equipped with bailing tanks, it could unwater the mine faster than it had been filled.

Since mining operations had stopped and the workings had been

abandoned above the 1000-ft. level, it had been noticed that the air in these places had rapidly lost its oxygen through oxidation of the pyrite and timber. The heat had also diminished, and samples of air taken in these old stopes by the Bureau of Mines had shown the following composition:

	Sample No. 1, Per Cent.		Sample No. 2, Per Cent.
CO ₂	4.11	CO ₂	3.39
O.....	1.68	O.....	5.19
N.....	94.21	N.....	91.42

This was apparently an inert atmosphere and one in which spontaneous combustion could not occur. If the flooding should be successful in extinguishing the fire, it appeared possible that conditions above the 1000-ft. level could be duplicated below by sealing off all openings to old workings by concrete bulkheads and driving new ventilating raises at places away from all contact with the old stopes.

Numerous other details were considered, but the above-mentioned reasons were the main ones discussed in conferences with Mr. Shilling, Superintendent of the Utah Copper Co., and Mr. Sheehan, Superintendent of the Tintic Mining and Development Co. These men recommended flooding the mine, as did also Mr. Pope Yeatman, who had recently examined the mine and was familiar with conditions. On the morning of Mar. 27, 1917, orders were received to flood the mine, and by 5 o'clock in the afternoon all tools cars, electric locomotives and pumps had been removed from the lower levels.

Flooding

The main air line was disconnected near the shaft, and the outside end of the line connected with the surface fire pump. As soon as possible, the station pumps which had been removed were also put in operation on the surface, and wherever possible all natural drainage was diverted to the lower levels. On the morning of Mar. 28, the volume of smoke coming up No. 10 raise was so great that it was impossible to go to the shaft. This condition grew rapidly worse, and on Apr. 1 the top of this raise resembled a smokestack, emitting great quantities of dense wood smoke. Some time during the night the water must have reached the fire, for on the following morning the atmosphere in the mine cleared rapidly, and about noon it was possible to go to the shaft and measure the water level for the first time. Pumping was continued steadily, and daily measurement taken until Apr. 10, when the mine had been filled to approximately the 1100-ft. level.

As soon as the flooding started, a bailing tank was designed and two were ordered. Unwatering was begun on the evening of Apr. 20. The new hoist was used for the first time, and the tanks were discharged at the tunnel level. Two shaft men on each shift, using the sinking hoist

and bucket in the end compartment, looked after the tanks, attending to the removal of floating timber and other details.

Good progress was made until the water was lowered to about the top of the 1300-ft. level station. At this point the tanks rested on the landing chairs and would go no deeper. Bailing was continued as carefully as possible, in the hope that, even with partly filled tanks, it might be possible to lower the water sufficiently to enable the shaft men to get chains around the chairs and pull them up, but this could not be done. One of the tanks stuck at the bottom and could not be pulled up. When the shaft men went down to see what had happened, they were suddenly plunged into a strange gas about 50 ft. (15 m.) above the water. Their lamps were put out, and it was only through the best of fortune that they were able to give the signals to be pulled up. Later, this gas was found to be mostly nitrogen and carbon dioxide, the latter having been formed at the time of the fire and confined in blind headings and stopes beyond the fire zone. Bailing was continued with the other tank; in a few hours this also stuck, but at the 1150-ft. level, safely out of the water. Air was turned down the regular lines, and the column pipe, but on the following day no change in the level of the gas nor in its strength was noticed. The sinking bucket would bring the gas up just like water, but blowing had no perceptible effect.

On the day the fire was discovered, six sets of Draeger 2-hr. breathing apparatus, and a month's supplies for these sets, had been ordered. This material had arrived on Apr. 20, and a crew was slightly trained in its use. Storage-battery lamps had also been secured. The helmet men did splendid work, considering the difficulties. Guides were torn out continually, and finally one compartment of the shaft was fitted with long pieces of 4 by 6, which extended a short way under the water. These pieces were placed at short intervals all around the compartment, and the tanks was fitted in so tightly that it was impossible for it to miss sliding onto the guides when pulled out of the water. It was then possible to drop the tank with sufficient force to give it a pile-driving effect, and the chairs were soon knocked out and fell out of the way. Bailing was continued with this tank, the lining being extended from time to time until the water was several feet below the station. Permanent repairs were then made to the other compartment, and bailing was resumed in it until the water had been lowered far enough to make repairs in the compartment first used.

As soon as the tanks were working smoothly again and the level was cleared of water, the helmet crew was able to walk into the level and open air valves near the stopes. This rapidly drove the gas out to the shaft, where the tanks carried it up into the fresh-air current. In a few days, it was possible to begin cleaning up the level without the use of breathing apparatus. Two helmet men, however, were held in readi-

from the time flooding was begun. Had it not been for the delays on the two stations, the flooding and unwatering would have taken only a few

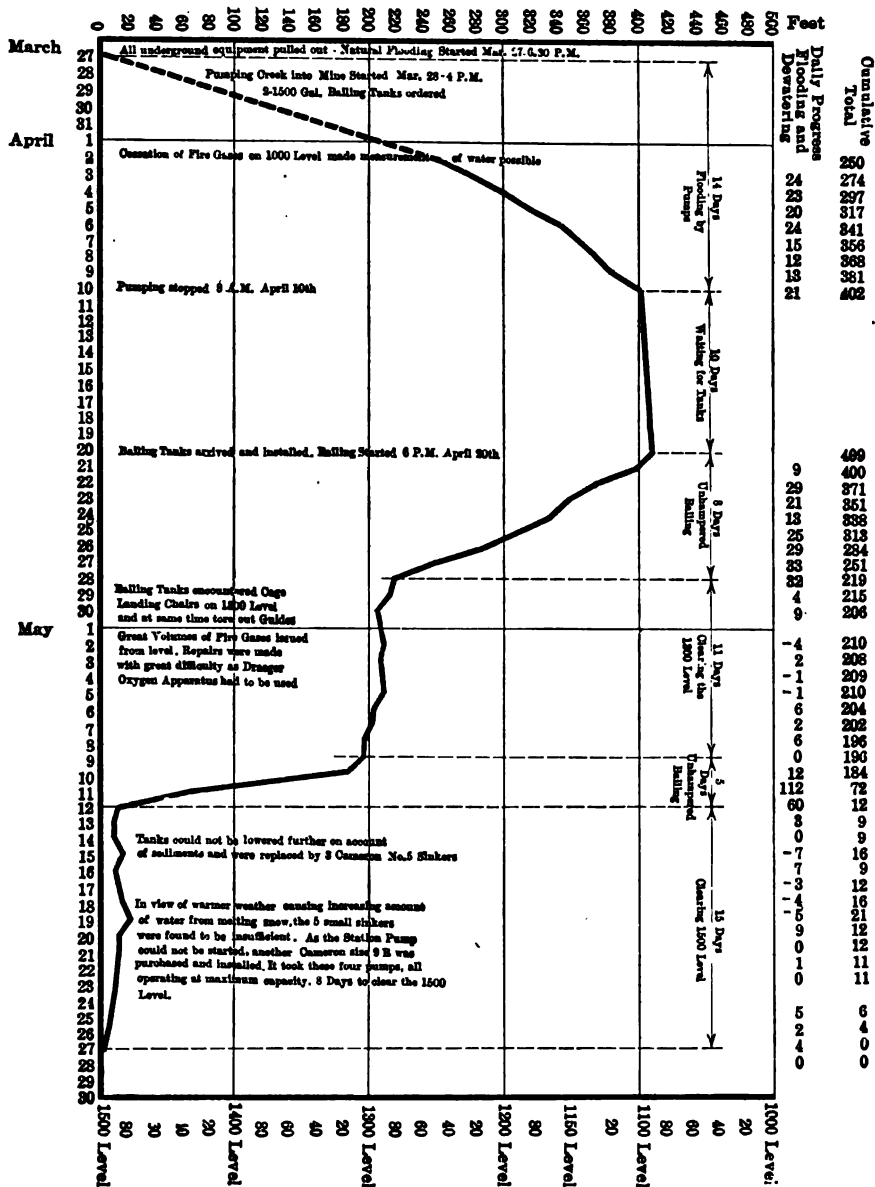


FIG. 3.—MINE FLOODING AND DEWATERING.

days over one month. The accompanying chart shows graphically the progress of this work.

CONDITIONS AFTER THE FIRE

Condition of Workings

As soon as the station pumps were again in place, the tanks were removed and the regular cages placed in service. Cars were sent to all the levels, and cleaning up started. Most of the mud was found on the 1500-ft. level, averaging 1 ft. thick. The greater part of this was a thin slime and was washed out to the pumps. Little mud was found on the other levels. Most of the mud had come from the muddy creek water which was pumped into the mine at the time of flooding. In the neighborhood of the orebodies, the drifts and raises were found practically blocked with fine ore which had run through the cracks in the lagging. The slices in the stopes had practically run full of ore, but the timbering everywhere was in fine condition, and the working places had only to be shoveled out. Four thousand tons of ore, mostly clean-up material, the cost of which was charged to the fire, was shipped in June. Nine thousand tons were shipped in July and 16,600 tons in August, the latter being the largest tonnage month of the year. The accompanying statement shows in detail the costs of fighting the fire and cleaning up the levels and stopes. It covers a period from Mar. 27 to June 30. Undoubtedly some of the post-fire conditions hampered July operations, but as the tonnage was nearly normal and the work difficult to distribute, no charge was made against the fire in this month.

Preventive Measures

As fast as the levels were cleaned up, concrete bulkheads were placed at all openings leading to the fire zone. In August, samples of the air behind the bulkheads were taken, and showed the following analysis:

	1150 Level, Per Cent.		1300 Level, Per Cent.
CO ₂	10.00	CO ₂	8.53
O.....	1.70	O.....	4.59
N.....	88.00	N.....	87.00

Flooding cooled everything to the natural temperature of the water, and there has apparently been no heating behind the bulkheads since they were put in place. New stopes, started below the 1300-ft. level since the fire, have become warm, but as soon as a stope has been finished all openings will be sealed, and it is hoped that in this way future trouble will be avoided.

In conclusion, the thanks of the company are extended to Messrs. Shilling and Sheehan for their good counsel and suggestions relative to fire-fighting methods. All the neighboring mines were prompt to offer

any aid in their power, and this action was greatly appreciated. To the helmet crew, the company is particularly indebted, and has endeavored to express its appreciation in the form of bonuses and better positions. Its thanks are also given to all its employees who through their loyalty and energetic efforts helped greatly in the time of need.

Itemized Account of Expenses Incurred During the Period of Recent Mine Fire at the Utah-Apex Mine, Bingham, Utah

Mar. 27 to June 30, 1917

	Labor	Supplies	Total
Preparing to flood:			
Taking out machinery.....	482.38		
Construction of dam and flume.....	62.63	4.85	
	545.01	4.85	549.86
Flooding:			
Direct operating.....	462.31	238.84	
Watching dam.....	117.00	0	
Steam power.....	497.30	344.00	
Electric power.....		950.54	
Miscellaneous charges.....	238.50	81.89	
	1,315.11	1,615.27	2,930.38
Preparing to unwater:			
Construction of flume and tunnel under portal of Parvenu tunnel to Bingham Creek.....	307.57	52.15	
Raising 1000-level station and installation of tank trips.....	392.67	84.47	
	700.24	136.62	836.86
Unwatering:			
Auxiliary hoists.....	725.22	4.05	
Surface hoist (actual tanking).....	832.71	331.39	
Electric power.....		3,791.79	
Steam power.....	545.85	635.26	
Bailing tanks.....	364.37	3,308.77	
Direct operating.....	1,112.94	681.14	
Hazardous work requiring the use of breathing apparatus.....	1,105.48	647.57	
Repairs to shaft and equipment.....	827.78	887.30	
Miscellaneous charges.....	367.50	274.33	
	5,881.85	10,561.60	16,443.45
Preparing to resume mining:			
Cleaning up levels.....	8,183.71	847.97	
Construction of concrete bulkheads.....	738.12	200.19	
Surface hoist.....	91.56	20.56	
Steam power.....	205.62	239.12	
Electric power.....		1,000.26	
Replacing and connecting pumps.....	301.21	95.81	
Miscellaneous charges.....	186.29	115.28	
	9,706.51	2,519.19	12,225.70

Overhead expenses:

Supervision.....	1,361.47		
Timekeeping	356.00		
Barn expense.....	183.25	140.16	
	1,900.72	140.16	2,040.88

Total fire expense..... **\$35,027.13**

Equipment Installed, Value of Which was not Consumed During the Fire

3000 ft. of 6-in. pipe line.....	959.68	4,160.69	
Cement gun.....	21.94	1,345.51	
6 sets Draeger breathing apparatus.....	9.00	1,360.07	
	990.62	6,866.27	7,856.89

Total fire and equipment expense..... **\$42,884.02**

DISCUSSION OF THIS PAPER IS INVITED. It should preferably be presented in person at the Colorado Meeting, September, 1918, when an abstract of the paper will be read. If this is impossible, then discussion in writing may be sent to the Editor, American Institute of Mining Engineers, 29 West 39th Street, New York, N. Y., for presentation by the Secretary or other representative of its author. Unless special arrangement is made, the discussion of this paper will close Oct. 1, 1918. Any discussion offered thereafter should preferably be in the form of a new paper.

The Relation of Sulphides to Water Level in Mexico

BY P. K. LUCKE,* SAN ANTONIO, TEX.

(Colorado Meeting, September, 1918)

ONE of the interesting features connected with the great continental uplift, which formed the table land of Mexico, is the great depth to which oxidation and secondary enrichment of orebodies occurred. This table land lies at altitudes ranging from 4000 to 7000 ft. (1219 to 2133 m.) above sea level. Several cases could be cited of oxidized zones in copper and lead mines which reached depths of upward of 1500 ft. (457 m.) below the surface, and it is universally admitted that the oxidized zone in a mine is limited by the permanent water level.

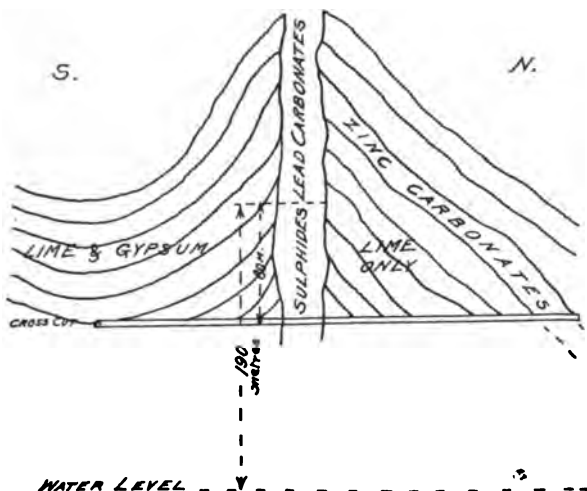


FIG. 1.

Mexico, however, like many other countries in which deserts occur, is visited at rare intervals by tremendous floods, which sometimes cause variable water levels over long periods. The following cases bear out the idea, and lead to interesting conclusions of commercial value. My paper demonstrates that carbonates of ores may occur below water level and sulphides above, and I will endeavor to explain the causes of the phenomena in certain specific instances.

Case I.—Fig. 1 in this case shows that sulphides of lead remained

* Consulting Mining Engineer.

unoxidized 190 m. (623 ft.) above water level, while carbonates of zinc will probably continue down to water level. The cross-cut bisecting the anticline affords the following data: The south side of the anticline shows gypsum and limestone interbedded, while the north side contains only limestone. Immediately contiguous to the lead orebody, massive gypsum occurs, and the body of ore is in sulphide form at the level of the cross-cut and for a distance of 80 m. (262 ft.) above it.

The zinc orebody, on the other hand, has extended to the cross-cut level in carbonate form, and will probably remain in oxidized condition to the water level. The explanation of this condition is probably that the gypsum resulting from the oxidation of the lead orebody has cemented

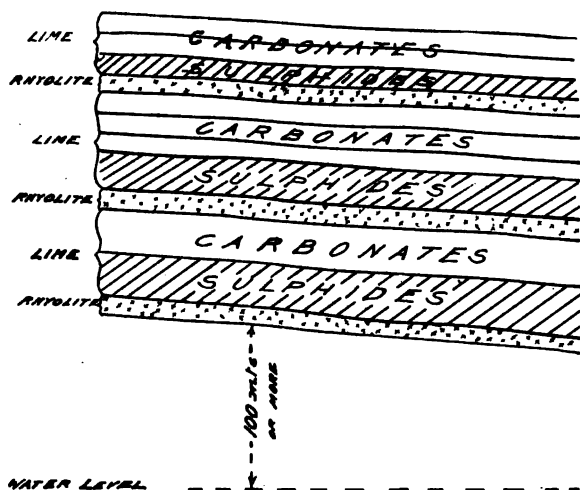


Fig. 2.

the bedding planes of the limestone underneath and to the south side of the anticline, thus damming back the surface waters, which under normal conditions would have oxidized the ore down to the permanent water level.

On the north side of the anticline, as stated, no cementing of the bedding planes by gypsum occurs, and it was therefore possible to predict that oxidation of the zinc orebody would probably continue down to the water level, and development has proved that the prediction was justified.

Other cases of local occurrences of sulphides above water level could be mentioned, but one more will suffice for the purposes of this paper.

Case II.—The lead-silver orebodies occur in this instance in a series of more or less vertical fractures cutting interbedded limestone and rhyolite. Fig. 2 illustrates the example. While the water level has not been reached, it probably lies at a depth of from 100 to 200 m. (328 to 656 ft.) below the

deepest workings in this mine, sulphides remain unoxidized immediately above the interbedded igneous rock, but owing to the surface waters having found their way on the line of ore shrinkage represented by the foot-wall of that rock at the various horizons, oxides of lead and zinc are found overlying the sulphides. This curious alternation of oxidized ore and sulphides will probably continue in depth until water level is reached, and an increase in the thickness of sulphides in comparison to that of the carbonates may be looked for at each successive horizon. When water level is encountered, no more oxides will be found unless Case III is duplicated in this camp, which is possible.

Case III.—Lead and copper ores occur in this example in irregular chimneys which originated in fractures in Cretaceous limestone, and the present water level lies at a depth of 350 to 400 m. (1148 to 1312 ft.) below

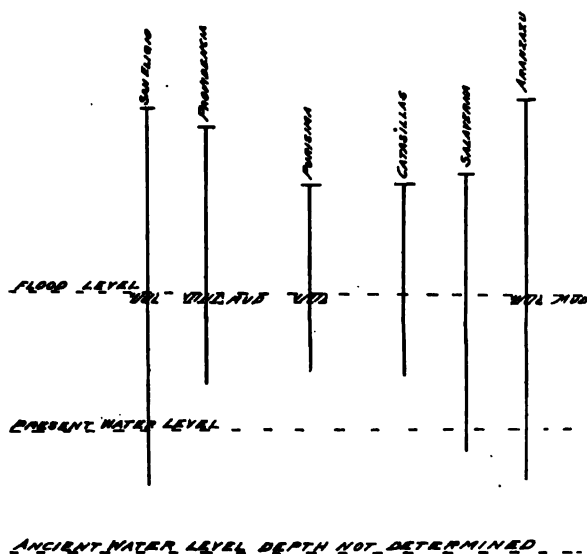


FIG. 3.

the surface. In the Aranzazu, San Eligio and Salaverna mines, carbonates have been found at depths as great as 100 m. (328 ft.) below the present water level. In three mines in the district under discussion, and 100 m. (328 ft.) above water level, good orebodies have bottomed in valueless mud. The mud in one case was 20 m. (65 ft.) thick, and, in each case below the mud, valuable ore has been found again and continues downward.

It is fair to conclude, therefore, that the mud represents the highest level reached by the floods, and that the present water level is receding to greater depths, as otherwise carbonates of the ores would not persist below the present water level. It is well to note, also, that no marked

zone of enrichment has yet been encountered, which would certainly be the case if the permanent water level had been reached.

The above conclusions are of commercial importance to the district, and probably to others also, as the original sulphides, when encountered, will probably be of low grade, although certain lead mines may become paying copper mines when the sulphide zone is reached.

As my statement with regard to the probability of the original sulphides being of low grade may be questioned, I will qualify it by stating that in my opinion the majority of the large oxidized orebodies in the table land of Mexico owe their high values to secondary enrichment, which takes place under ideal conditions in respect to water level and climate. The value of carbonate ores in Mexico is therefore no indication of the value of original sulphides.

It is also reasonable to conclude from the foregoing that:

1. The discovery of original sulphides, showing no secondary enrichment, above permanent water level is possible but not usual.
2. The discovery of a local water level high above the known water level of the district is a fairly common phenomenon, and when found indicates the presence of local sulphides.
3. Even if a high local water level be found, it is still possible, under favorable conditions, to find that oxidation occurs beneath the local sulphide zone indicated by it.
4. Many present water levels, especially those in desert countries, may rise and fall over considerable distances and periods of time, and do not necessarily decide the limits of the carbonate zones in mines, although they may warn us of the proximity of sulphides.

DISCUSSION OF THIS PAPER IS INVITED. It should preferably be presented in person at the Colorado meeting, September, 1918, when an abstract of the paper will be read. If this is impossible, then discussion in writing may be sent to the Editor, American Institute of Mining Engineers, 29 West 39th Street, New York, N. Y., for presentation by the Secretary or other representative of its author. Unless special arrangement is made, the discussion of this paper will close Oct. 1, 1918. Any discussion offered thereafter should preferably be in the form of a new paper.

Geology of the Oil Fields of North Central Texas

BY DORSEY HAGER,* TULSA, OKLA.

NORTH CENTRAL Texas has recently become a center of interest for the oil men of America. The bringing in of the McClosky well at Ranger, Eastland County, and the shallow pool at Brownwood, Brown County, in 1917, has stimulated interest in this area to fever pitch. Oil men from all over the United States are now investing there. The area of present interest is shown by the accompanying map (Fig. 1).

The money spent in leases runs into millions of dollars. It is no exaggeration to say that a strip of country 200 miles (321 km.) long and 125 miles (201 km.) wide, comprising some 15,000,000 acres (6,070,310 ha.), has been leased practically solid at a cost for rentals and bonuses of at least \$1 per acre. The test holes contracted for will certainly number 400, at a cost of at least \$5,000,000. From what has been done in the past six months, \$20,000,000 at least will be spent. To pay returns on this amount of money, new production to the extent of at least 12,000,000 bbl. must be obtained. At present, the production from new fields will not average over 5000 bbl. per day; three wells at Ranger are producing 3000 bbl.; 250 wells at Brownwood produce 1000 bbl.; and the Gray well, Coleman County, is as yet an unknown factor.

However, at Ranger there is every indication of developing a good pool covering from 1500 to 2000 acres (607 to 809 ha.), more or less, but the wells are deep, 3400 to 3800 ft. (1036 to 1158 m.), and cost \$35,000 to \$40,000 to drill. Large wells are necessary to pay for such expensive holes. As new wells are drilled, the gas pressure will be lowered rapidly, and large production need not be expected. For those oil men who expect a second Cushing or an Eldorado, Ranger holds little of promise.

At Brownwood, Brown County, there are some 250 shallow wells (depths from 200 to 350 ft.) averaging 4 to 7 bbl. per day. There is a chance of an extensive producing area for these shallow sands to the southwest, and the opening of several thousand acres of shallow oil territory, and also some promise of deeper oil horizons in the Ranger horizon, but probably all under 2500 ft.

At present, the lease brokers and speculators, and only a handful of oil men, have made any money. More fields must be developed, and it is more particularly with these possibilities that this paper deals.

* Petroleum Geologist and Engineer.

Lack of water for drilling purposes has undoubtedly held back development so far this year; this part of Texas has had a drouth for two years and there is an actual scarcity of water. Geological investigations so far undertaken cover nearly all the area outlined, and while part of the area has not been closely worked, it is not too early to make some definite statements as to the probable prospective pools.

GENERAL GEOLOGY

The present oil pools lie in the Carboniferous belt of rocks (Fig. 1) consisting of sandstones, limestones, and shales belonging to the divisions shown in the accompanying outline (Table 1). The names are peculiar to central Texas, and are derived from towns where these beds were first studied in detail by early investigators.

TABLE 1.—*Stratigraphy of Central Texas*

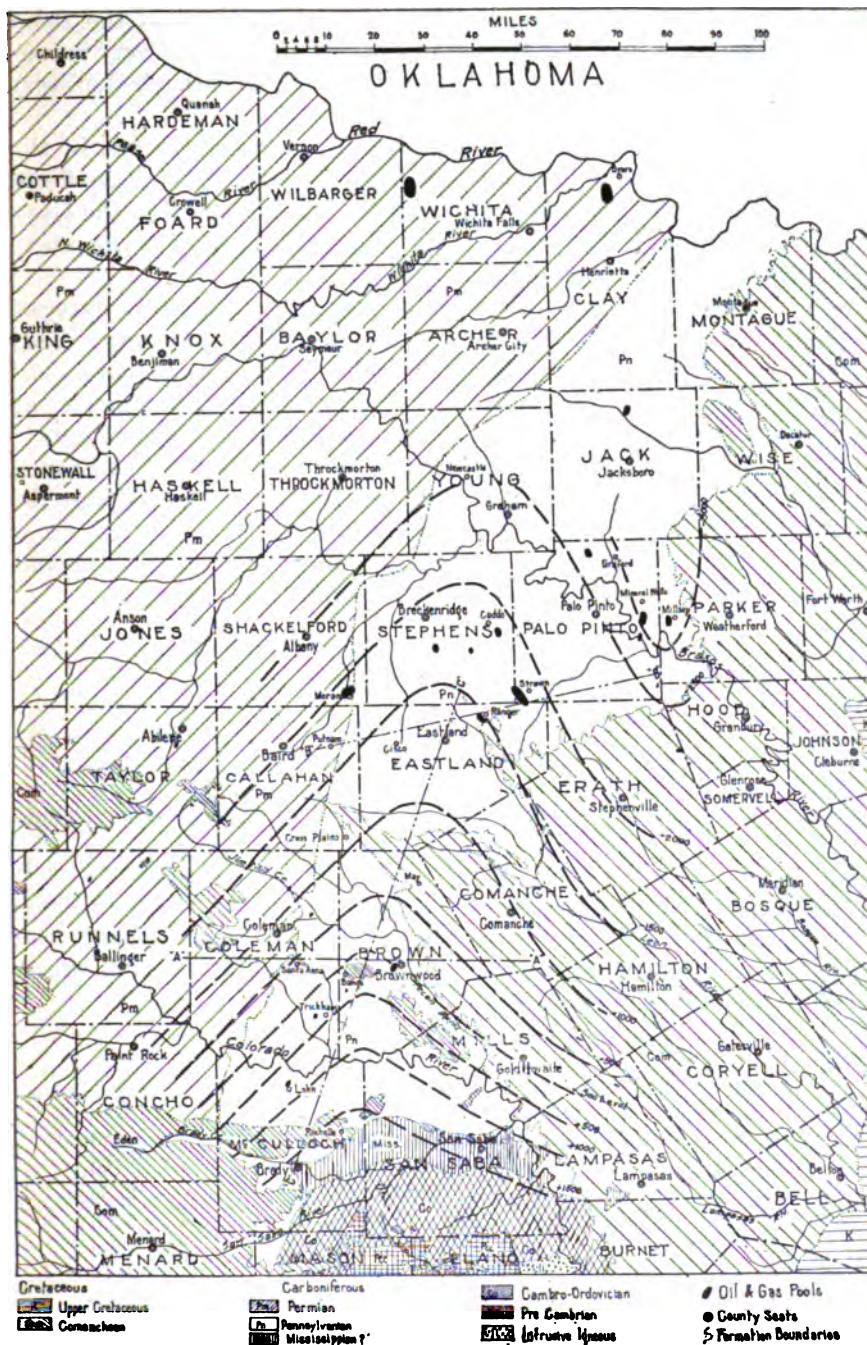
Mesozoic	Cretaceous	Comanche beds	Sandstones, shales, limestones	Thickness feet
				200-500
Carboniferous	Permian	Albany—Wichita	Principally limestones, shales	1200
	Pennsylvanian	Cisco Canyon Strawn	Limestones, shales	900
			Shales, limestones	600-800
	Mississippian	Bend series, } 800-1000 ft. }	Principally shales, sandstones	2500-4000
			Smithwick shale	400
			Marble Falls limestone	450
			Lower Bend shale	50

For the relation of these beds to one another see Fig. 2.

The Bend series carries the Lower Bend shale, the Marble Falls limestone, locally called the Bend limestone, and the Smithwick shales.

The Bend limestone is probably the producing horizon at Ranger, Eastland County; at Parks, near Breckenridge, Stephens County; at Caddo, Stephens County; at Coleman, Coleman County, in the Magnolia deep test; and of the gas in the Magee well southwest of Bangs, in Brown County. The productive horizon in the Bend limestone may be at the top, at the bottom, or in the middle of the limestone series, depending upon the porosity of several beds; the Bend limestone is not homogeneous, but comprises limestones which vary greatly in porosity and hardness. In places, the limestones are parted by thin shale bodies.

In the writer's opinion, the "sands" or "reservoirs" are most prob-



ably thin beds of cherty conglomerate. At the outcrop of the Bend south of San Saba and also Richlands Springs, thin beds of very porous chert are found at the base of the Bend, as well as through the lower part of the formation.

The Smithwick shale series, or upper Bend, produces gas in the Chestnut well, 9 miles (14 km.) south of Mineral Wells, Palo Pinto County, the oil at Trickham, Coleman County, and the oil in the Gray well northeast of Coleman, Coleman County. The sandy members in the shale series are the productive horizons.

The Strawn horizon produces at Strawn, in Palo Pinto County; at Millsap, Parker County; and at Moran in Shackleford County. This horizon carries good sands, or, more properly speaking, sandstones.

The Canyon series produces oil at Brownwood, Brown County; at Lohn, McCulloch County; and a little oil near Abilene, in Taylor County.

The Cisco horizon produces the deep wells at Petrolia and at Electra in Clay and Wichita Counties, and the shallow oil at Moran, in Shackleford County. This oil occurs in sandstones.

The Albany-Wichita beds produce the shallow oil at Electra and Petrolia. The producing horizons here are sandstones.

TABLE 2.—*Specific Gravities of Some Texas Oils*

Fields	Degrees B ₆	Remarks
Strawn.....	40.0	
Caddo.....	39.5	
Ranger.....	39.0	Dark green color.
Brownwood.....	40.0	Dark amber color
Millsap.....	44.0	Pure amber color; 50 per cent. gasoline.

From this review, there are at least six distinct oil horizons, each containing separate sands, from one to three in number, in the Carboniferous beds, notably the Bend limestone, the Smithwick shales, the Strawn, the Canyon, the Cisco, and the Albany-Wichita beds, which are all producers at different places.

TABLE 3.—*Producing Sands*

Oil Field, and County	Producing Horizons	Depths to Pay Sand, Feet
Abilene, Taylor	Cisco (Penn.)	2100
Brownwood, Brown	Canyon (Penn.)	90-350
Caddo, Stephens	Bend (Miss.)	3150
Coleman, Coleman	{ Smithwick (Miss.)	2350
	{ Bend (Miss.)	3400
Electra, Wichita	Albany (Penn.)	200-1000
Gray, Coleman	Smithwick (Miss.)	2412
Millsap, Parker	Strawn (Penn.)	2150
Moran, Shackleford	Cisco (Penn.)	350-2150
Parks, Stephens	Bend (Miss.)	3150
Petrolia, Clay	{ Albany (Permian)	200
	{ Cisco (Penn.)	1800

Ranger, Eastland	Bend (Miss.)	3428
Strawn, Palo Pinto	Strawn (Penn.)	700-1100
Santa Anna, Coleman	Smithwick (Miss.)	1560
Trickham, Coleman	Smithwick (Miss.)	1020-1200

Probable Stratigraphic Range of Oil Fields

There is no logical reason why the basal Permian beds should not produce oil; below it are the Upper Pennsylvanian beds, which, 75 miles (120 km.) west of Santa Anna, should be reached at a depth of 3000 ft. (914 m.). In fact, there seems to be no reason for contesting the possibilities of oil over an area at least 125 miles in width and 200 miles long.

The only argument against production in these upper beds is the scarcity of sandstones in the basal Permian and in the Cisco, upper Pennsylvanian. Some sands are present, however; their persistence is the only question. However, the Permian horizon does produce in the northern part of the area described, notably at Electra and Petrolia, and there is no good reason for assuming that it will not produce in the southern part of the area.

The Cretaceous Unconformity

A feature of much importance is the Cretaceous unconformity, so pronounced in this area in Texas. Fig. 2 shows the relation of the over-

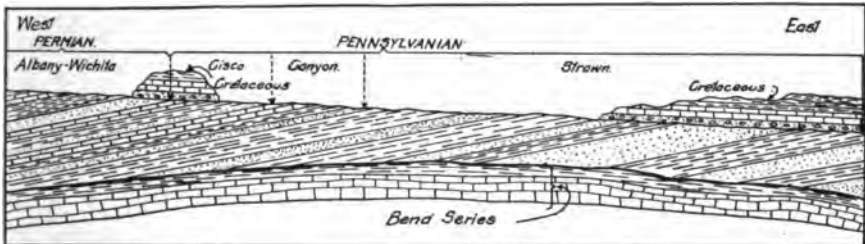


FIG. 2.—STRATIGRAPHY OF NORTH CENTRAL TEXAS.

lying Cretaceous beds to the underlying Pennsylvanian and Mississippian. The gentle regional dip of the Cretaceous beds is eastward, and of the Pennsylvanian westward. The Mississippian corresponds with neither series of beds.

The Cretaceous caps a large area of the Strawn beds in the eastern part of this area. One can see no reason why production may not be found in the Strawn beds hidden under the Cretaceous cover. In several places, folds carry right into the Cretaceous beds, notably the Bull Creek and the Ebony anticlines in Mills County. Other folds probably lie hidden under the Cretaceous, but the only way to discover such folds is to prospect for them with the drill; a set of shallow tests might uncover something that might later justify deep testing.

GEOLOGICAL STRUCTURE

In no other areas are ordinary haphazard wildcatting methods so

excusable as here, since the geologist can be of little assistance in guiding initial prospecting.

The most significant feature of all these oil pools is their relation to structural folding of the beds; every pool so far discovered occurs on a fold. This folding is of three general types: (1) closed domes (Fig. 3); (2) plunging anticlines, called noses (Fig. 4); (3) terraces (Fig. 5). True closed structure is scarce, although some closed folds have been discovered. Electra and Petrolia may be classed as of true dome types; Moran, Strawn, Ranger, and Coleman are terraces on the surface. Other folds of the terrace type are found near Brownwood. In Mills and San Saba Counties, true closed domes are known. These folds have full closures of 50 to 80 ft., and are unusually large for Texas.

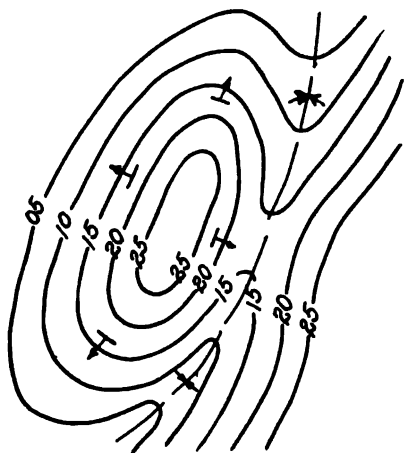


FIG. 3.—CLOSED DOME.

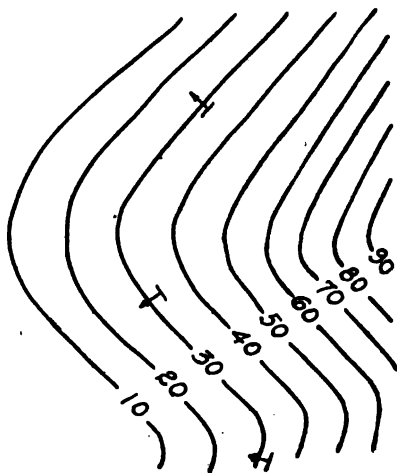


FIG. 4.—PLUNGING ANTICLINE.

From all the evidence at hand, the folds that may reasonably be expected to develop the pay fields will be mainly of the types shown in Fig. 4 and 5. The true dome type, which is the usual producing structure in South Texas, Oklahoma, Kansas, Wyoming, and California, is uncommon, though present, in northern Texas. The Saline dome, as found in the Gulf Coast area, is absent here. The folds thus far discovered seem to have been formed by lateral pressures, not by the peculiar upward bulging in connection with salt cores, so common further south.

Size of Structures

The folds vary in size from small wrinkles of no commercial value up to several thousand acres in size; however, the known prospective folds are mostly small, ranging from 320 to 2000 acres of favorable land. At least 50 folds having prospective value have already been discovered and leased in this broad area.

Direction of Folding

Three sets of folds exist in Texas, having axes trending respectively: (1) Northeast-southwest; (2) northwest-southeast; (3) north-south. Most of the folds extend in a northeast-southwest direction, while the northwest-southeast are next in number. The former, roughly parallel to the strike of the beds, might be called strike folds, while the latter can be called dip folds. As the normal or regional dip of the surface beds is northwest throughout the Pennsylvanian and Permian areas, the important reversal on all folds is to the southeast and the northeast.

Persistency of Folding with Depth

It is interesting to note that on most of the folds already drilled through the Smithwick shales and the Bend limestone, commercial oil or gas has been found. This is notably the case at Ranger, at Breckenridge, at Caddo, at Coleman, at Trickham, and the Magee Field south of Bangs. This seems to show that folding in the Upper Pennsylvanian persists into the Mississippian horizon; probably following a line of earlier folding.

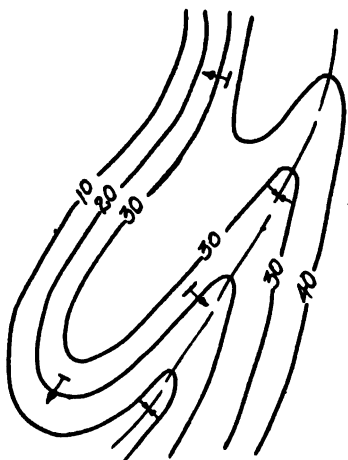


FIG. 5.—TERRACE.

Relation of Smithwick and Bend Series to Overlying Beds

One of the most interesting and important subjects at present is the relation of the underlying Bend horizon to the overlying beds. This oil horizon is the main deep prospective measure in the minds of the oil operators, and is perhaps too much emphasized at present.

The Pennsylvanian beds overlying the Bend series dip west at a rate of 60 to 90 ft. per mile (11.4 to 17.1 m. per km.), the dips diminishing from east to west; but the underlying Bend does not dip accordingly, as shown by the records of the deep wells thus far drilled to the Bend; also, from conditions near the outcrop of the Bend (see cross-sections AA, BB and CC, Fig. 6, 7 and 8 respectively).

Bend Arch

An important structural feature apparently underlies the Pennsylvanian beds, according to evidence derived from outcrop and well records. This feature is what the writer designates the Bend Arch, a large plunging fold which extends northeastward from the outcropping beds in San Saba and McCulloch Counties (see contours on map). The cross-section (Fig. 6, 7, and 8) shows the general relationship of the Bend to the overlying beds.

The importance of this fold lies in the fact that one looks for local oil accumulation in the minor folds upon it, and also that it materially affects estimates of depths. The contour lines on the map are drawn with 500-ft. (152-m.) intervals, and will unquestionably be modified by additional data. They are based on the top of the Bend

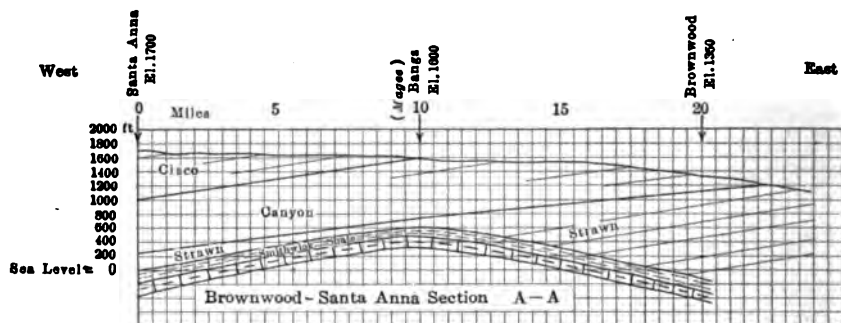


FIG. 6.

limestone as a datum, and are corrected for mean sea level. The writer expects faulting and perhaps other large folds to appear with further detailed study. The average north dip in the Bend is 32 ft. per mile (6 m. per km.).

Section AA indicates a cross-section east and west across the fold. Brownwood, there are 1100 ft. (335 m.) of Strawn shown by well records;

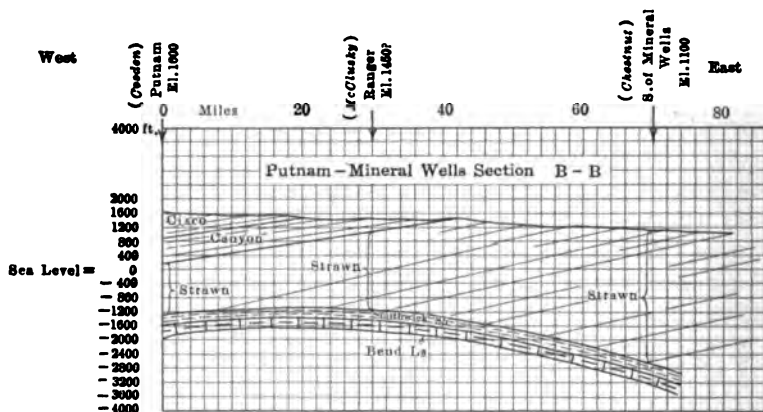


FIG. 7.

near Bangs, 200 ft. (61 m.); and at Santa Anna, 200 ft. Wells at Coleman, northwest of Santa Anna, show about 700 ft. (213 m.) of Strawn. There is a marked convergence between the Strawn from Brownwood to Bangs, The Strawn beds outcrop $3\frac{1}{2}$ miles (5.6 km.) east of Brownwood. At and then the Strawn runs nearly parallel to the Bend and does not thicken appreciably until west of Santa Anna.

It will be noticed, in the cross-sections, that very little Strawn is present on top of the big arch in the Bend, especially in the area from Bangs south to Rochelle. Along this line, production, if any, will come from the Canyon, the Smithwick shales, and the Bend horizons. East of this line, the Strawn may produce. Wells so far tested west of this fold have produced oil and gas in the Smithwick shales at Santa Anna and at Coleman, and below the Bend limestone at Coleman.

Section *BB* shows the condition from the Chestnut well, $9\frac{1}{2}$ miles (15 km.) south of Mineral Wells, across Ranger to Putnam. The Chestnut well shows 3600 ft. (1097 m.) of Strawn; the Ranger well 2200 ft. (670 m.); and the well at Putnam, 1400 ft. (427 m.) more or less.

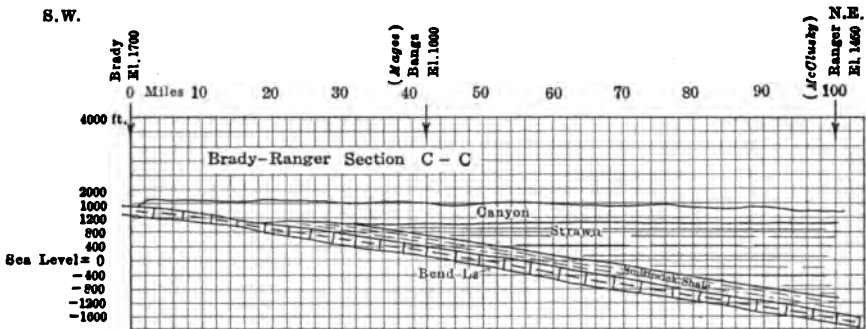


FIG. 8.

Section *CC* shows the relation of the beds from Brady, in McCulloch County, to Ranger. At Brady, the Canyon lies unconformably on the Bend. Further north, near Bangs, 200 ft. of Strawn is shown, while at Ranger 2200 ft. of Strawn is present, showing a marked thickening of the Strawn beds northward along the axis of the fold.

A study of the cross-sections *AA*, Fig. 6; *BB*, Fig. 7; and *CC*, Fig. 8, is of great interest. One is struck at once with the marked fold in the Bend showing in *AA* and *BB* and the changes in the thickness of the Strawn. The Strawn normally dips northwest. Its strike varies from N. 30° E. to N. 50° E. The strike of the Canyon and Cisco beds is N. 20° E. with a northwesterly dip.

Possibility of Oil Migration from Smithwick Shales to Strawn Horizons

Another point that may be of interest is the possibility that the Smithwick shale, a black carbonaceous shale, is the source of oil in the Strawn. The Strawn beds lie unconformably on the Smithwick shales, and it would be a simple matter for oil to leave the Smithwick and enter the Strawn at the point of contact, without crossing bedding planes (see Fig. 2). Folds in the Strawn beds will form traps or reservoirs

for this migrating oil, and are worth testing, not only in the Smithwick and Bend horizons but also in the Strawn. In the writer's judgment, new pools will be opened in the Strawn series.

SUMMARY

1. At least six producing horizons, from Mississippian to Permian, are found in this area of Texas. Each general horizon carries one or more pay sands.

2. The areal extent of the probable pools comprises a strip 200 miles (321 km.) long and 125 miles (201 km.) wide.

3. The Cretaceous beds cover some good prospective land which is worth prospecting. The geologist can be of but little assistance there.

4. All pools so far discovered are on structures such as domes, terraces, and plunging anticlines.

5. The folds are not large, 300 to 2000 acres (121 to 809 ha.).

6. At least 50 untested folds are known to geologists.

7. The direction of folding is mainly northeast-southwest. Some northwest-southeast and north-south folding is found.

8. The Pennsylvanian beds lie unconformably on the Mississippian series.

9. The Bend Arch is an important new structural feature, deduced from drill records and outcrops. It may assist in governing accumulation, and influences estimates of depths to the Bend producing horizon.

10. The migration of oil from Smithwick shales to Strawn beds is possibly due to the angular unconformity between the two series. This may largely account for oil in the Strawn series.

11. The above review indicates a possibility of numerous small pools in north central Texas, varying in depth from 250 to 4000 ft. (76 to 1219 m.). Stratigraphic and structural conditions are favorable, and most of the folds so far tested have proven productive.

ACKNOWLEDGMENTS

In presenting this paper, the writer wishes to thank Messrs. Leon Pepperberg, C. T. Griswold, Robt. T. Hill, Lee Hager, and Dilworth Hager, for valuable suggestions and information, and also to thank Robt. Jordan of Mineral Wells and Mr. Robinson of Santa Anna, for courtesy in furnishing well records. The writer has drawn freely from the *Texas State Survey Bulletin* for nomenclature and description of the geologic formations.

Much of the matter is new, however, and some of the correlations and conclusions may be open to question, so the writer invites discussion to clear up the doubtful points.



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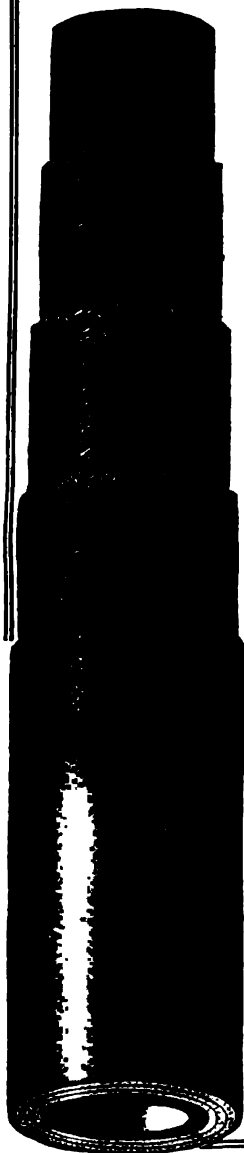
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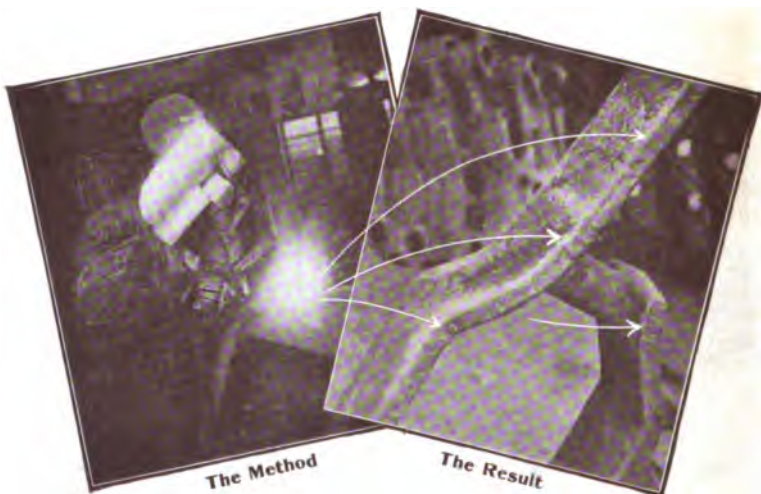
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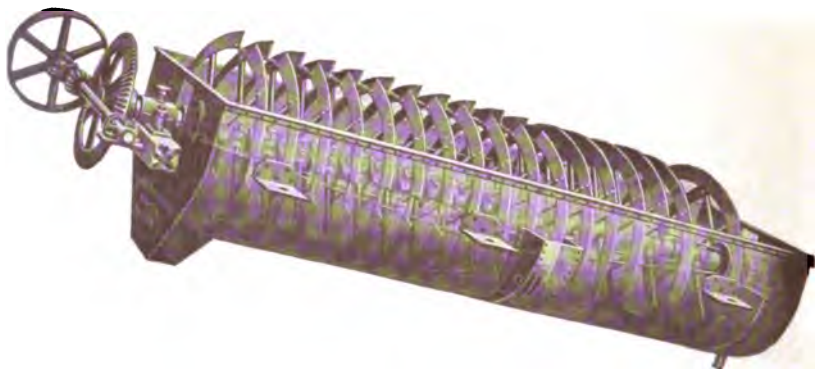
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COLORADO MEETING COMMITTEES

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BULLETIN OF THE AMERICAN INSTITUTE OF MINING ENGINEERS

PUBLISHED MONTHLY

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COLORADO MEETING

Arrangements for the annual summer meeting of the Institute, to be held in Colorado during the week beginning Sept. 1, have been nearly completed. Announcement of details cannot be made at this time, but the general plan has been outlined about as follows:

A registration booth will be opened at the Brown Palace Hotel, Denver, Sunday, Sept. 1. All members are requested to register here on that day, if possible. An organization meeting will be held early Monday morning, Sept. 2, at the Brown Palace Hotel, and the remainder of the day will be devoted to technical sessions, visiting points of interest near Denver and an auto trip over the Lookout Mountain drive, with a dinner in the evening.

Members can take trains late the same evening or early the following morning for Colorado Springs, where a get-together meeting will be held at the new two million dollar Broadmoor Hotel which expects to open for business before that time. After luncheon at the Broadmoor, technical sessions will begin, and be continued as time permits to the close of the meeting.

Trips to the Cripple Creek District and Pueblo are contemplated; at the former place, the low-grade ore mills of the Portland Co. will prove of much interest. It is planned to visit both the lead and zinc smelters at Pueblo, the plants of The Colorado Fuel & Iron Co., and more particularly the new byproduct coke ovens which are now nearing completion.

One of the special features of entertainment will be the automobile drive to the top of Pikes Peak. Optional trips to the Leadville District

and the great deposits of molybdenite ore at Climax, near Leadville, have been suggested, and it is probable that some arrangement will be made to visit the ferro-tungsten plants at Boulder.

The meeting will close at Colorado Springs with a dinner at the Broadmoor Hotel.

The members of the Colorado Section are very anxious to make this meeting a success in every respect.

MEETING OF THE BOARD OF DIRECTORS, MAY 29, 1918

Twelve Directors, the Secretary, and ten guests were present.

It was unanimously resolved that the sense of this body is that the name of the Institute should be changed to American Institute of Mining and Metallurgical Engineers. Messrs. J. W. Richards and Bradley Stoughton were appointed a committee to formulate the necessary steps for bringing the matter to a vote.

The committee in charge of the New York meeting, with Allen H. Rogers, Chairman, was appointed.

The rules of the American Engineering Standards Committee were approved.

The *Bulletin* was presented to the Springfield Arsenal.

The sum of \$250 was appropriated to the Southern California Section. The By-laws were changed to increase the Secretary's cash from \$500 to \$1000.

The report of the Treasurer was accepted.

Sixty-eight members, thirteen associates, and forty-eight junior associates were elected. Four members were reinstated. The resignations of seven members were accepted. Thirteen members on active duty at the front had their dues remitted.

Upon the recommendation of the Finance Committee, it was resolved that the dues of any members who have attained the age of seventy (70) years and have been members for a continuous period of at least thirty (30) years shall be remitted.

The following resolution regarding enemy aliens was passed:

RESOLVED: That all Honorary Members, Members, Associates, and Junior Members who are Enemy Aliens residing in enemy countries be dropped from membership in the American Institute of Mining Engineers and their names be and they are stricken from the rolls.

RESOLVED: That the Membership Committee be requested to advise this Board of Directors of the names of all above-mentioned persons and in addition the names of all other enemy alien members of the Institute, and be it further

RESOLVED: That in the case of each of said latter class this Board shall consider and act upon the question of expulsion after ascertaining their attitude toward the Government of the United States.

RESOLVED: That publicity of these resolutions be given to members through the Local Sections and by publication in the *Bulletin* as well as through the daily press.

g
U.S. Geol. Survey

HOSPITALITIES EXTENDED TO AMERICAN ENGINEERS IN FRANCE

The following very cordial letter, addressed to the President of the American Institute of Mining Engineers by the President of the graduates of the School of Mines of Saint-Étienne, will be deeply appreciated by all American engineers and will perhaps be of use to engineers going "Over There." Members are requested to communicate the substance of this letter to friends or acquaintances in France:

Dear Mr. President:

Now that the American armies are crossing the ocean to come to our side in the defence of the liberty of the world, and the intellectual élite of your great country is very ably coöperating with us in this supreme struggle, we ardently desire to give them a whole-hearted reception upon their arrival on the shores of France.

The representatives of your illustrious association will be more especially welcome among their French colleagues, and both at Saint-Étienne and at Paris, we desire that their sojourn be rendered comfortable and congenial in every way possible.

We therefore put ourselves unreservedly at their disposal. At Paris especially those of our colleagues

Mr. Pitaval, Ingénieur civil des Mines, 7 rue d'Offémont,

Mr. De Catelin, Ingénieur civil des Mines, 27 rue Laffitte,

Mr. Chastel, Ingénieur civil des mines, General Director of the Society of Penarroya, 12 Place Vendôme,

who speak the English language fluently, are anxious to act as their guides on all occasions.

This coöperation of American and French engineers will draw closer the ties of mutual responsibility, which at the present moment should more than ever unite them in the defence of the same ideal of progress.

Please accept, Mr. President, the expression of our sentiments of cordial fraternity.

The President, P. PETIT.

MEN NEEDED ON SUBMARINES

It is desired to call the attention of young men who have had technical training and experience to the fact that their abilities can best be put at the service of the country by selecting a branch of service in which their special qualifications will be of the greatest use.

The submarine force of the United States Navy requires the services, as officers on board submarines, of young men who have had technical training in mechanical and electrical engineering and who have had experience in these professions. It is intended to enroll a number of such men as provisional ensigns in the Naval Reserve Force, give them a course of instruction in deck duties at Annapolis and a course in submarine work at New London. Those who successfully pass these courses will then be sent on board submarines for regular duty.

It is requested that any men who desire this duty and who are qualified as below outlined send their names and addresses to the Commander Submarine Force, *U. S. S. Chicago*, care of Postmaster, New York.

Qualifications required:

Desire to serve in submarines.

Degree of M. E., E. E., or E. M.

Two and one-half years' practical experience in profession.

Not over 35 years old.

Physically strong and sound.

Candidates should, if practicable, receive the indorsement of one of the following organizations:

Naval Consulting Board.
National Research Council.
American Society of Mechanical Engineers.
American Institute of Electrical Engineers.
American Institute of Mining Engineers.

CONANT TAYLOR, *Lieutenant-Commander, U. S. Navy.*

NATIONAL RESEARCH COUNCIL

MADE PERMANENT BODY

Executive Order

The National Research Council was organized in 1916 at the request of the President by the National Academy of Sciences, under its congressional charter, as a measure of national preparedness. The work accomplished by the council in organizing research and in securing coöperation of military and civilian agencies in the solution of military problems demonstrates its capacity for larger service. The National Academy of Sciences is therefore requested to perpetuate the National Research Council, the duties of which shall be as follows:

1. In general, to stimulate research in the mathematical, physical, and biological sciences, and in the application of these sciences to engineering, agriculture, medicine, and other useful arts, with the object of increasing knowledge, of strengthening the national defense, and of contributing in other ways to the public welfare.

2. To survey the larger possibilities of science, to formulate comprehensive projects of research, and to develop effective means of utilizing the scientific and technical resources of the country for dealing with these projects.

3. To promote coöperation in research, at home and abroad, in order to secure concentration of effort, minimize duplication, and stimulate progress; but in all coöperative undertakings to give encouragement to individual initiative as fundamentally important to the advancement of science.

4. To serve as a means of bringing American and foreign investigators into active coöperation with the scientific and technical services of the War and Navy Departments and with those of the civil branches of the Government.

5. To direct the attention of scientific and technical investigators to the present importance of military and industrial problems in connection with the war, and to aid in the solution of these problems by organizing specific researches.

6. To gather and collate scientific and technical information, at home and abroad, in coöperation with governmental and other agencies, and to render such information available to duly accredited persons.

Effective prosecution of the council's work requires the cordial collaboration of the scientific and technical branches of the Government, both military and civil. To this end representatives of the Government, upon the nomination of the National Academy of Sciences, will be designated by the President as members of the council, as heretofore, and the heads of the departments immediately concerned will continue to coöperate in every way that may be required.

THE WHITE HOUSE,
11 May, 1918.

WOODROW WILSON.

RESEARCH INFORMATION COMMITTEE

By joint action the Secretaries of War and Navy, with the approval of the Council of National Defense, have authorized and approved the organization, through the National Research Council, of a Research Information Committee in Washington with branch committees in Paris and London, which are intended to work in close coöperation with the offices of the Military and Naval Intelligence, and whose function shall

be the securing, classifying and disseminating of scientific, technical and industrial research information, especially relating to war problems, and the interchange of such information between the Allies in Europe and the United States.

In Washington the Committee consists of:

- (a) A civilian member, representing the National Research Council, Dr. S. W. Stratton, Chairman.
- (b) The Chief, Military Intelligence Section.
- (c) The Director of Naval Intelligence.
- (d) A Technical Assistant, Graham Edgar.

The Committee in London consists of:

- (a) The Scientific Attaché, representing the Research Information Committee, Dr. H. A. Bumstead, Attaché.
- (b) The Military Attaché, or an officer deputed to act for him.
- (c) The Naval Attaché, or an officer deputed to act for him.
- (d) A Technical Assistant, S. W. Farnsworth.

The Committee in Paris consists of:

- (a) The Scientific Attaché, representing the Research Information Committee, Dr. W. F. Durand, Attaché.
- (b) The Military Attaché, or an officer deputed to act for him.
- (c) The Naval Attaché, or an officer deputed to act for him.
- (d) A Technical Assistant, K. T. Compton.

The headquarters of the Research Information Committee in Washington is in the offices of the National Research Council, 1023 Sixteenth Street; the Foreign Committees are located at the American Embassies in London and Paris.

PRESENTATION OF THE JOHN FRITZ MEDAL TO J. WALDO SMITH

On April 17, the John Fritz Medal, the award of which the presiding officer, Col. John J. Carty, characterized as "the highest honor which can be conferred on an engineer in America," was presented to J. Waldo Smith "for his most distinguished services in civil engineering, and particularly in connection with the work on the great aqueduct, which has just been completed."

Col. Carty spoke very briefly of the origin of the Medal and the method of awarding it, mentioning the names of the twelve men to whom it has been awarded in former years, and then introduced Mr. Nelson P. Lewis, Vice-president of the American Society of Civil Engineers, and for many years Chief Engineer of the Board of Estimate of the City of New York, who is an old colleague and fellow-engineer of Mr. Smith. Mr. Lewis said, in part:

Mr. Smith is so well known that an extended review of his professional activities will be unnecessary, but a brief outline of the development of a conspicuously successful hydraulic engineer may not be out of place. It would be difficult to find a better instance of the success which is quite sure to result from persistent devotion to all phases of a particular line of engineering work. It began in his boyhood, when, as a lad of 15, he eagerly availed himself of such opportunities as were afforded to help in the construction of a waterworks system for his home town in New England. It was a very modest plant, consisting of a small reservoir and pumping station, and about 4 miles of pipe. Probably it was the most important improvement the town

had undertaken, and he not only tried to make himself generally useful on the work, but made it the subject of his school compositions and essays. That his interest was intelligent and his volunteer work was of real value is shown by the fact that, several years later, when a vacancy occurred, he, though still a boy of 17, was given charge of the operation of the plant, acting as fireman, engineer, and general superintendent of the work.

This experience appears to have brought a realization of the need of a thorough scientific education, and, after two years in charge of these works, he entered the scientific course at the Phillips Andover Academy. Then followed two years of service with a water-power company, where much time was devoted to the measuring of water. His technical education was not yet complete, but was rounded out by the full engineering course at the Massachusetts Institute of Technology, his summer vacations being devoted to practical work with a water-power company.

In 1890 he became connected with the East Jersey Water Company, and for the next 13 years was engaged in the construction of an extensive system of reservoirs and pipe lines to supply a number of towns in Northern New Jersey, his work here culminating in the design and construction of the filtration plant at Little Falls, which was at the time the largest in the United States.

In 1903 the Aqueduct Commissioners of New York City wanted a chief engineer, and the position was offered to and accepted by Mr. Smith. The large new Croton Dam was then under construction, and the necessity for its prompt completion was believed to be imperative. The work was pushed energetically, and the impounding of water began within the following year.

In 1905 came the opportunity for which Mr. Smith's experience had peculiarly qualified him. The project of the Catskill Water Supply for New York had been finally authorized, and the Commission created by the statute selected Mr. Smith as Chief Engineer.

Great technical skill in design, however, even when coupled with capacity to plan an organization to execute efficiently, may not produce the desired results, in the absence of certain human qualities which stimulate enthusiasm and promote good team work. Fortunately, Mr. Smith possessed these qualities in a conspicuous degree. Not only was the plan of organization admirable, but rare judgment was shown in the selection of the department and division engineers.

But the Chief Engineer of so great an undertaking must deal with many others besides his own engineering staff, and in these relations there is need of the exercise of diplomacy combined with firmness, insistence on rigid enforcement of obligations, coupled with absolute fairness and shrewdness, as well as kindliness. To what degree these qualities were shown will, doubtless, be indicated by another speaker.

The next speaker, the Hon. A. T. Clearwater, of Catskill, was introduced as "a public man, a jurist, a lawyer, and a citizen of New York, who has attended, as a member, two of the Constitutional Conventions of this State." The following paragraphs are quoted from his speech:

I have known Mr. Smith ever since he dawned above the horizon of the Catskills. I have differed with him upon many, many occasions. I expect to differ with him upon many, many to come. And yet, notwithstanding these differences, you will be surprised—some of you will be shocked—I know, to hear me say that I have a great admiration for him, an admiration predicated upon his sterling character, his great scientific attainments, the scientific attitude, the intellectual detachment, the desire to be sure, and to be right, which has characterized his conduct as the Chief Engineer of this colossal work. . . . The characteristics of Mr. Smith's efforts have been exactness, accuracy, and veracity. . . .

This man is a wonderful diplomat. He has that singular faculty of never seeming to insist upon his own way, and of getting his own way every time that he starts out to get it. Now, is not that the first quality of a diplomat, and has it not been one of the crowning features of his career?

And he has attained it, without—as Machiavelli, as Rochefoucauld, as Voltaire, and as Rousseau have all said—he has managed to attain it without lying; and you will remember that they all said that a diplomat was a man sent abroad to lie for the benefit of his country. We have been able to rely upon what he said—I will not say that he said very much. I think I might say that a subdued reticence was the great characteristic of his conversation; but what he did say was reliable.

You all have seen the Cathedral of St. Paul's in London, built by the great architect, Sir Christopher Wren. When it was proposed that they build, in place of the statue of Queen Anne in the Plaza in front of St. Paul's, a monument to Sir Christopher, it was suggested by the Mayor and the Commonalty of the City of London that they put an inscription on that cathedral which would surpass in dignity, and in a lesson to posterity, any monument which they might devise or erect; and they placed on the walls of St. Paul's an inscription which might well be placed on the Ashokan Dam to the memory of Mr. Smith: *Si Monumentum Requiris, Circumspice*.

The Medal was presented by Mr. Ambrose Swasey, Past-president of the American Society of Mechanical Engineers, and Chairman of the John Fritz Medal Board at the time the award was made.

In accepting the Medal, Mr. Smith said:

It is idle for me to pretend that I am not deeply moved with the tribute of this meeting. I would be insincere were I to create the impression that I am not most grateful for the generous, gracious words of this talented scholar and distinguished jurist from Ulster County, and of the ranking engineer of the City of New York in commendation of the work accomplished. For the very beautiful and artistic medal, typifying the highest honor in the gift of engineers, I am profoundly grateful and appreciative. I shall never cease to be filled with wonder and surprise that I was chosen for this honor, a wonder which only grows with consideration of the previous recipients.

On the other hand, it gives me great pride, joy, and happiness to think that it is an honor in which very many others can rightfully claim a large share. Some are in this room; some are serving the Government in its present-day vital activities; and some are in a far country fighting the battles of their nation and of humanity. It would be the height of presumption to assume that this medal was not intended as a recognition of the construction of the Catskill Water Supply, and of the work of all those who have contributed to its success, and I do so consider it.

In conclusion, Mr. Smith addressed a few words to his "personal associates" who were present, saying that he wished to share with them any honor or credit that he might receive. He thanked them for their loyalty and for the ability, vision and talent they brought to the work, and said:

The whole underlying, fundamental reason of all the success is this cordial coöperation and consideration which each has felt for the other; and the fact that the administrative and executive bureaus have worked together and in perfect harmony and have believed in each other.

ENGINEERING SOCIETIES LIBRARY—NOTABLE GIFTS

During the past 20 years the Westinghouse Electric & Manufacturing Co. and the General Electric Co. have collected a valuable library of some 9000 volumes on electricity. The collection was intended especially for use in patent searches and is particularly rich in patent material. Files of all the principal patents relating to electric light and power issued by America, England, France and Germany, are present, together with copies of the patents owned or controlled by the two companies. Another feature, and one of unusual value, is a series of volumes containing the records of the important adjudicated patent cases of these companies and their predecessors during the past 25 years, and forming a storehouse of electrical history. There are also files of about 100 electrical periodicals.

It is a pleasure to announce that this collection has now been presented by the owners to the Engineering Societies Library. This gift, which was arranged through Mr. Charles A. Terry, Vice-president, Westinghouse Electric & Manufacturing Co., and Mr. Charles Neave, Counsel,

General Electric Co., was made with the thought that the collection would be useful to many engineers if housed in an easily accessible situation. It is an unusually valuable accession, for which the Library authorities are deeply grateful.

The books have been transferred to the Engineering Societies Library, where they may now be consulted.

During April, Mr. Jesse M. Smith presented nearly 400 volumes and pamphlets selected from his private library, consisting of engineering periodicals, and of records of patent cases with which Mr. Smith has been connected.

Mr. Putnam A. Bates has presented large portfolios, containing a set of the drawings for the New York City fire alarm system, which will prove interesting to engineers.

Dr. F. H. Newell has collected and presented a number of interesting publications relating to the Council of Engineering Societies on National Public Works, which was active in attempting to reform the policy governing the conduct of public works in this country during the eighties.

Space forbids the mention of many other gifts, but these have in nearly every case been of decided value to the Library, and have been appreciated also as evidence of friendly interest in its success. It is hoped that every member will bear the needs of the Library in mind and present from time to time any new or old engineering material which he can spare. General coöperation will bring to its shelves much scattered material which cannot be obtained in any other way.

HARRISON W. CRAVER, *Director of Library.*

LOCAL SECTION NEWS

BOSTON SECTION

ALFRED C. LANE, *Chairman*, GEORGE A. PACKARD, *Vice-chairman*,

E. E. BUGBEE, *Sec'y-Treas.*, Mass. Inst. of Technology, Cambridge, Mass.

R. L. AGASSIZ,

FRED W. DENTON.

Forty-sixth Meeting

The forty-sixth meeting of the Boston section was held at the University Club on Monday evening, Jan. 28, 1918. Thirty-six members and guests were present, which is a record for this Section.

After a good dinner, President Philip N. Moore, of the Institute, was introduced, and spoke of the many problems of the Institute. The topics covered were the progress and growth of the Institute during the administrative year, the efforts to stimulate the local sections and to bring them more in touch with the policies and problems of the parent body and, last but not least, of the constructive results and patriotic work of the Institute in the national service of the war.

The other guest of the Section, Mr. Thomas Nelson Perkins, Counsel for the Priority Board, spoke most entertainingly of recent experiences in Russia, England and France.

After considerable discussion during which Mr. Perkins most obligingly answered innumerable questions, the meeting adjourned at about 10 p. m.

Forty-seventh Meeting

The forty-seventh meeting, the seventh annual meeting, was held at the University Club on Friday evening, March 15, 1918, 24 members being present. After the usual dinner, the Treasurer submitted his report, which was accepted and ordered placed on file.

The report of the Nominating Committee was next read and the Secretary was instructed to cast one vote for the men proposed. The officers listed above were thereby elected for the ensuing year.

There were present as Section guests, J. Parke Channing of New York, Bradley Stoughton of New York and C. W. Goodale of Butte, Mont., Secretary and First Vice-president respectively of the parent society.

Mr. Channing, the principal speaker of the evening, read a most interesting paper entitled "Man Power."* After considerable discussion by a number of members present, Mr. Stoughton was introduced.

He spoke of the problems of the Institute and particularly referred to two matters requiring a change in the Constitution which the members are likely to be called to vote upon. They were brought up at this time to elicit discussion. The first of these pertained to a change of name of the society, with the idea that the large body of metallurgists in the society should be recognized in name. The American Institute of Metals desires an affiliation with our society and wishes to be known as the Institute of Metals Division.

The second change relates to the proposed publication every three years by the Institute of an Autobiography of Members which would be sold to members by subscription. Both of these proposals were discussed at considerable length by a number of members.

Mr. Lane moved the adoption of the following resolution:

"The Boston Section requests the Officers of the A. I. M. E. to ask the United States Fuel Administration to fix the prices for coal from the mine to the consumer upon a certain standard heating value, as determined by analysis or calorimeter test, and that deductions or additions to these prices depending upon its greater or less heating value be permitted.

"Also to request that, inasmuch as it would lead the mines to send the most concentrated fuel to the farthest points, and inasmuch as it costs no more for freight and takes up no more room to handle a high-grade fuel than one adulterated with slate or other non-heat-producing material, the mines be allowed to receive payment for extra heating value up to the amount it is worth to the consumer."

After some discussion, the motion was seconded by Mr. Wentworth and carried.

Mr. Goodale was next introduced and spoke of going to Great Falls, 20 years ago, and finding Mr. Channing's figures for "Man Power" in use there. His own observations regarding man power were mentioned and it was stated that in the change from 10 to 8 hr. in the Butte mines the "tons per man per day" did not fall off. This would indicate that an 8-hr. shift in mining is as long as a man can work efficiently.

The "ten-day men" of Butte were mentioned in connection with the labor turnover requiring 15,000 men on the pay rolls to get an average of 10,000 regular workers per month.

* *Bulletin* No. 137 (May, 1918), 963.

Prohibition goes into effect in Montana on Dec. 31, 1918, and Mr. Goodale next spoke of the problem of taking care of the men which would then arise. The Anaconda company is, of course, in favor of prohibition and expects the new Y. M. C. A. building to help but not entirely to meet the situation.

The "Rustling Card" was next discussed and the objection of some of the men to stating where they had previously worked was explained. The I. W. W. particularly resisted this apparently harmless measure, and is encouraged in this stand by Jeanette Rankin, Congresswoman from Montana.

In discussion, Mr. Channing brought out the fact that in Arizona it was illegal to ask a man where he had previously been employed.

Forty-eighth Meeting

The forty-eighth meeting was held at the Engineer's Club on Monday evening, May 6, 1918. The meeting was preceded by an informal dinner at which 14 members and guests were present.

The minutes of the meeting of March 15 were read and approved. After remarks by the new chairman, Professor A. C. Lane, Mr. A. H. Eustis presented a paper on "The Smelter Smoke Problem and the Making of Liquid Sulphur Dioxide at West Norfolk, by the Virginia Smelting Company." The trouble was started as usual by a neighboring farmer who sued for damages to his crops, and as truck farming in the neighborhood of Norfolk is an important industry, it became apparent that the smoke nuisance must be abated or the smelter would have to move. How this was successfully accomplished for converter, Dwight Lloyd sinterer and chloridizing roaster fumes was recounted in a most interesting manner.

The next question was what disposition to make of the tower and scrubber liquors. The original intention was to run these solutions into the harbor, but, owing to a suit instituted by oyster growers about this time, it was thought best to remove most of the sulphur dioxide before doing this. The sulphur dioxide recovery system was next described. Lantern slide projections illustrated the various features of the process and plant. A sample of the product was exhibited. It looked harmless enough in a Seltzer bottle, but everyone agreed that the next time Mr. Eustis gives this demonstration he must supply gas masks for all.

EDWARD E. BUGBEE, *Secretary*.

NEW YORK

Meeting of March 26, 1918

The March meeting of the New York Section was held at the Engineers' Club on March 26. About 65 members of the Section attended the dinner preceding the meeting, and about 100 were present by the time the Chairman, Mr. J. E. Johnson, Jr., called the gathering to order. The purpose of the meeting was to discuss labor and employment problems. Addresses were made by Messrs. Sidney J. Jennings, Walter Douglas, J. Parke Channing, Edwin Ludlow, E. E. Southard and A. H. Young.

J. E. JOHNSON, JR.—The relations of employers to labor should be based, first, on justice, second, on intelligent coöperation between both sides. We have seen that the ability of the English to “carry on” depends on their power to persuade the laboring people to go along with them and carry their program through. From the point of view of production, no other question is so vital as the understanding of labor and employment problems in their broadest aspects. One of our members suggested that it would be desirable to devote a meeting to this subject: I have therefore asked several gentlemen to address us tonight, most of whom are operating officials in big companies, and understand the question thoroughly.

SIDNEY J. JENNINGS.—On studying the history of company organization, I find that the root idea of the company originated under the Roman law; the Roman *collegium* was the forerunner of the present-day company; it had a common chest, and could possess property in common. That idea was handed down through the ages, until in England of the seventeenth century, we find the idea of dividing up the property of a corporation into shares. The intention was to have a lot of small investors holding shares in an enterprise and thereby giving it strength. But this practice became so great a nuisance, everybody being solicited to take shares in all sorts of enterprises, that in 1790 the so-called “Bubble Act” was passed, which declared a company to be a public nuisance, and ordered it to be closed. Thereafter, nobody was to be allowed to issue shares, excepting a certain privileged number of companies which should be chartered by the Crown or by private act of Parliament.

In 1845, the idea of limited liability became prevalent in England; and in 1862 the Consolidated Companies Act was passed, consolidating all acts which had been passed between 1845 and 1862. It is under that charter that the giant stock and limited-liability companies of the present day have developed; so that the company, as we know it, is a very modern thing. It is a development of the last two generations, and has not, therefore, any of that sacrosanct character of antiquity; hence if we find that this device, which interposes itself between the employer and the laborer, is merely a legal entity having no body to kick and no soul to damn, and does not properly fulfill the duty which it has assumed, it will have to be done away with, possibly as a public nuisance.

The effect of this enormous development of the corporation has been widely different on the three classes of people chiefly involved. First, as to the capitalist: when he invests his money in a corporation he frequently feels that he is divorced from responsibility for his wealth. We often see a man owning bonds and shares who has no sense of responsibility as to how his dividends or interest are earned; and thus his sense of human brotherhood deteriorates.

The second class are the managers of corporations. These carry enormous responsibility and exercise great power, often without actual possession of wealth. Too often, the manager says, “What I do is right, because I am doing it for some third party, who asks and requires me to do it.” Too often, he opposes his own sense of what is right and just in order to satisfy demands which ought not to have been made.

The third class are laborers, who often feel that they are mere cogs in a wheel; sometimes they are not treated as human beings, but merely as hands pushed by muscles in order to achieve results.

These are the most serious errors entailed by the tremendous growth of the corporation, and it is the duty of us engineers and operators to attempt to minimize them.

One of the main provisions of the Consolidated Companies Act was that publicity should attend the actions of a corporation. You invite every willing person to become a partner in a corporation; therefore, it seemed only just to the law-makers of England, and, in time, I believe it will also appeal to the law-makers of America, that every partner should be entitled to know what is going on in the corporation. There are, undoubtedly, certain details which might be called trade secrets, which should not be made public; but a very much larger degree of publicity than has existed in the past is, I think, a legitimate demand on the part of the investor and shareholder.

Many suggestions have been offered for offsetting the fact that a laboring man in the employ of a corporation feels that he is merely a cog in the mechanism and is not treated as a human being. One of the most successful of these methods is that adopted by the Steel Corporation, which says to every employee every year, "You may be not only an employee but also a partner in this enterprise, by purchasing shares." This seems to me a very excellent plan; it satisfies the ambition of the employee, because it gives him a chance to know more about the enterprise than what he sees going on immediately around him; the company managers also take the time and trouble to see that some of the larger questions and difficulties of corporation management are explained to the workmen, who then take an intelligent interest in affairs and do not make unreasonable demands.

Another method of interesting employees in the business, and making the relationship between them and the corporation more just and understandable, is division of profits. A friend of mine, who is in the business of making fittings for railroad cars, figured that his annual payroll amounted to practically the same amount of money as the capital he had invested in his business. He stated to his employees that he thought he was entitled to 6 per cent. on the capital invested, but if any dividends over 6 per cent. were paid on the capital, an equal amount should be paid to the laborers. Now, he has a most loyal and contented set of employees.

A third method of making this relationship more humane is the adoption of the employment manager idea. Under this plan, every man working for a corporation shall be engaged by one official, who will then send him to any shift-boss or foreman who needs a man. The shift-boss or foreman may later discharge the man from his gang but not from the company; the man merely returns to the employment manager, to whom he has a chance of explaining his difficulty. If possible, the employment manager will then find some other place where the man will fit, and may do good work. Nothing in this world is more difficult to guide than the human will; and there is no more tremendous force in this world than the human will. If you can get the will of all your employees to working for you the result will be success; if it is against you, the result will be failure.

WALTER DOUGLAS.—The relation of capital to labor in Arizona is a general problem rather than a special one; although we have endeavored to carry out a few plans which we hope may be a partial solution. I presume no problem today is exercising the operator or company

director more than this question of labor and the demands that labor is making. It is becoming increasingly difficult to get the point of view of the wage-earner. In the old days, when the mining companies that today are employing 4000, 5000 and 6000 men were employing 200 to 300 laborers, the problem was comparatively simple.

Many of you remember 20 or 30 years ago, when some of the great western enterprises were in their infancy, that the superintendent knew his men; he knew them by their Christian names, he knew their faces, generally he knew their families, and his political opinions and his religious opinions were largely reflected by the men. He talked to his men; they came to him with any little grievance and talked it over with him. Unfortunately, with the growth of business and the largely increased number of men employed, that close personal touch has been lost; nevertheless, some substitute for it must be found if satisfactory relations between laborer and employer are to be restored.

It is rather anomalous that when the average manager has a technical problem to work out—the construction of a new power house or a new mill—he engages a specialist and tries to get the very best man for that particular job, regardless of expense. I maintain that the labor question is of equal, if not greater, importance; and yet, the manager himself, who is overburdened with all the details of policy and operation, tries to handle the labor problem himself, and, as a rule, he falls down. In the first place, he probably is not temperamentally fitted to associate closely with labor. I believe that the difficulty can be solved only by the appointment of some intermediary between the manager and the workman.

In Arizona, a number of difficult conditions arise, due to the fact that the labor is of different nationalities in the several districts. Some are exclusively Mexican; others are Mexican and Spanish; in the coal mines we find Italians and the Balkan races. At the Copper Queen we have what is called a straight American camp; I believe, today, no one is being employed there who is not an American citizen. We adopted the suggestion of a general employment agent almost a year ago, and have taken away from the foreman the power of discharging a workman—he has not had the power of hiring for some years. If a foreman does not like any man who is working for him, the employment agent is the one who considers his discharge. He is able to investigate the reasons for laying off a man, and very often to transfer him from one division to another. This scheme was put into effect with the entire consent and agreement of the foremen and bosses, who were rather glad to get rid of the responsibility.

We have introduced a pension system at the Copper Queen, whereby a man who has worked for the company 15 years, and is physically incapacitated, receives a pension amounting to 2 per cent. of his salary for each year he has worked; a 15-year man therefore gets 30 per cent. of his salary. He may retire voluntarily, at the age of 60, provided he has worked for the company 15 years. The maximum amount paid is \$1000 per year. A number of men are now on the pension list. There is also a benefit association, to which the men subscribe, and the company contributes an amount practically equal to the amount contributed by the membership; 80 per cent. of the employees are members.

At the beginning of this year we inaugurated a new plan—a service bonus of \$100 to every man who had worked for the company more than a year, the idea being to pay a premium to the men who will stay with the com-

pany. There is no question that a man who is familiar with his work, and has become efficient in methods of mining a property like the Queen, is far more valuable than one who stays only a short time. It is probable that this plan will be adopted permanently throughout all our properties, and \$100 will be given to every man, irrespective of the wages he receives.

We have found that two of the principal subjects upon which labor agitators base their criticism are the company stores and hospitals. The company store was started in order to reduce the cost of living to the employees, and I think it has succeeded in its purpose. Interesting corroboration of this fact occurred recently at Globe-Miami, one of the largest camps in Arizona; over 90 per cent. of the employees there petitioned for a company store.

The hospital grievance has been a very pressing one, and it is hard to find any solution for it. If the companies do not run the hospitals, the men do not receive competent surgical attention. In Arizona the hospital deductions are practically nominal—from \$1 to \$2 per family man—for which the man and his family receive attention for all manner of accidents and sickness, even including confinement cases. Nevertheless, the labor agitator lays a great deal of stress on the enormity of the system.

The Arizona mining camps were very badly tied up last summer by strikes, initiated by the I. W. W., and in September the President appointed a Mediation Commission with the Secretary of Labor as Chairman, which he sent out in an endeavor to induce the striking laborers to resume operations, and to provide a plan for the prevention of strikes. That Commission was composed of three labor men and three capitalists, and a secretary nominated by the War Department. The proceedings of the Commission, as conducted by Secretary of Labor Wilson, were extremely dignified and instructive, and should have been published. Certainly, the conclusions published by the Department of Labor were not justified by the evidence given at the hearing. This Commission, however, devised a plan which is apparently working out very well. They eliminated the question of union recognition absolutely. They eliminated the I. W. W. by the preamble, which stipulated that any members of any union which does not recognize the sanctity of a contract should not be employed; nor any member who is disloyal to the United States Government. They then provided for the election of grievance committees and others who would confer with the management; and when they could not settle with the management, the matter was then to be taken up with the Federal Mediation Commission. So far, I am glad to say, it has not been necessary to take up any grievances with the latter.

[At the request of the Chairman, Mr. J. Parke Channing now read his paper, "Man Power," presented at a meeting of the Boston section on Mar. 15, 1918, and printed in *Bulletin* No. 137, May, 1918, page 963.]

J. E. JOHNSON, JR.—Those whose memories go back 16 years will recall the disastrous strike that covered the whole eastern half of the country, and cut off the fuel supply—how, after a long and bitter struggle, President Roosevelt jumped into the ring, brought both parties together, and by his moral pressure forced them, under the guidance of a commission appointed by himself, into a settlement, the basis of which has continued in effect, through renewals, and without any serious strike, from that time to this. We are fortunate in having as one of our members an operator who went through that experience, and is in a position to tell us a great deal about it—Mr. Ludlow.

EDWIN LUDLOW.—Mr Charles Schwab, in one of his recent speeches, said that labor was now one of our greatest problems, and probably all of us agree with him. We have always had our captains of industry, and we now have our captains of labor; henceforth, our industrial peace will depend upon the ability of the captains of labor and the captains of industry to get together at a council, and negotiate their agreements without strikes.

This is the method that has been practised in the anthracite region, with the result that there has not been a serious strike in that district since 1902.

The great Conciliation Board is almost unique in this country, and I think it will be interesting to go back a little into the history of its organization. In 1900, the long peace we had enjoyed in the anthracite regions was broken by the intrusion of the United Mine Workers, from the bituminous fields. The result of their agitation was a strike which lasted about six weeks. That being a presidential year, the politicians, not desiring to force matters to a conclusion, preferred to settle the difficulty in the easiest possible way, with least offense to all concerned; the result was a patched-up peace. Things drifted along in this unsatisfactory way until 1902, when the United Mine Workers felt that they were strong enough to enforce their demand for an eight-hour day, recognition of the union, and some other claims. On May 12, they called a strike of all the mine workers, and in June called out all the pumpmen and firemen. Police protection was lacking; the men who were willing to work were assaulted and beaten, which compelled the mine owners to turn each mine practically into an armed camp guarded by what they called Coal and Iron Policemen. Then the militia was called in and remained until the strike was settled.

In the fall, the shortage of coal became threatening, anthracite being worth about \$25 a ton in New York, and hard to get. In October, President Roosevelt stepped in and demanded that the strike should stop. This movement on his part was not at all to the liking of the operators, as they felt that they were virtually on the point of winning the strike; on the other side, the miners, who were on the verge of losing, were very glad to back up the President.

President Roosevelt appointed a commission. An agreement was made that the men should return to work pending the action of the Commission, and that, whatever the award was, it should be retroactive; that is, if the points raised by the men were decided in their favor, that the awards would date from their return to work.

The Commission spent considerable time in its investigations, and finally prepared a complete report, the essence of which was contained in a series of awards. The most important award, which has been the basis of all our Conciliation Boards, was the one in which:

The Commission adjudges and awards: That any difficulty or disagreement arising under this award, either as to its interpretation or application, or in any way growing out of the relations of the employers and employed, which cannot be settled or adjusted by consultation between the superintendent or manager of the mine or mines, and the miner or miners directly interested, or is of a scope too large to be so settled or adjusted, shall be referred to a permanent joint committee, to be called a Board of Conciliation, to consist of six persons, appointed as hereinafter provided. That is to say, if there shall be a division of the whole region into three districts, in each of which there shall exist an organization representing a majority of the mine workers of such district, one of said Board of Conciliation shall be appointed by each of said organiza-

tions, and three other persons shall be appointed by the operators, the operators in each of said districts appointing one person.

The Board of Conciliation, thus constituted, shall take up and consider any question referred to it as aforesaid, hearing both parties to the controversy, and such evidence as may be laid before it by either party; and any award made by a majority of such Board of Conciliation shall be final and binding on all parties. If, however, the said Board is unable to decide any questions submitted, or point related thereto, that question or point shall be referred to an umpire, to be appointed, at the request of said Board, by one of the circuit judges of the third judicial circuit of the United States, whose decision shall be final and binding in the premises.

The membership of said Board shall at all times be kept complete, either the operators' or miners' organization having the right, at any time, when a controversy is not pending, to change their representation thereon.

At all hearings before said Board, the parties may be represented by such person or persons as they may respectively select.

No suspension of work shall take place, by lockout or strike, pending the adjudication of any matter so taken up for adjustment.

The last provision has been of great importance to the operators. If any miner or group of miners has any grievance, he has to take it up with the foreman, and if they cannot come to an agreement, it is taken up with the superintendent; if an agreement is still unobtainable, the matter is carried up to headquarters by the president of the local, and they either agree on an adjustment there or else it is referred to the Conciliation Board. But during the entire consideration of this grievance, it is incumbent upon the men to remain at work, as no grievance can be heard by the Board unless they do so. There have been times when the men threatened to strike, and instances where a small number did strike, but the labor unions have always intervened and compelled them to return to work before any action would be taken on their grievance.

It must be borne in mind that all awards become retroactive; the miners therefore feel that they do not lose anything by delay, and because the Board does not have to make a quick decision, it is better able to determine the merits of a case. The early meetings of the Board were attended with some friction, the fight of 1902 being still fresh in mind, and nearly everything went to the umpire. But as the years have gone by—the miners having changed very little, as their president always represents them—a feeling of confidence has grown up, and the miners no longer feel that the operators are trying to take advantage of them.

One of the great advantages of the Conciliation Board is that it does not split any differences; it either grants the demand or refuses it, without compromise. It has been almost unknown for either the men or the companies to think of defying an award of the Board. In some cases when the men have made certain demands and have gone on a strike without submitting their grievance to the board the whole force of union labor has been brought to bear against them and they were forced to return to their work, before the matter would be taken up for consideration.

It is most important to get the confidence of the labor union leaders, and convince them that you are not trying to take advantage of them; as soon as this is accomplished, you have made great progress toward a satisfactory understanding. It is also a mistake to discourage your better class of men from joining the union; to do this is not to the best interests of the company nor of the men as a whole; in fact, it is almost dangerous. By keeping the better class of your men out of the union, you leave it in the hands of the radicals and the politicians. By encouraging the

strong men to join, you are then dealing with the best class of your workmen, and their steadiness helps to avoid strikes.

The Miners' Union has been a very strong factor in keeping out the I. W. W. In Scranton, the I. W. W. became very strong last year, and began to run the Union Mine Workers out of the camps. When they tried to break up a meeting the Union Mine Workers called on the State police to help them. Previous to that, the miners had been antagonistic to the State police and had fought them with more or less determination whenever the opportunity offered; but ever since that occurrence I have never heard them say one word against the State police.

J. E. JOHNSON, JR.—Everyone who has been thrown into contact with labor problems has had it forced upon his attention that some of the wisest men have a mental twist. They are fundamentally different in the make-up of their minds from the majority of their fellows, whether workmen or employers; and if you knew how to investigate a man's psychology, you could perhaps get to the root of his disorders. That movement is young as yet; but, personally, I believe it is of great importance and that it will not be long before we consider seriously the investigation of problems of this kind. We are fortunate in having with us tonight one who has studied all these problems—Dr. Southard.

DR. E. E. SOUTHARD.—The hospital with which I am connected, in Boston, is a State institution which has been operating about five years; about 3500 different patients go through that institution in a year. These persons are not so seriously affected that they ought to go direct to an asylum; but they are incipient cases of various sorts.

The point has been made that the superintendent alone is able to know all his men. To gain the advantage of this fact on a large scale, it will be necessary to provide a large number of superintendents and sub-superintendents. One cannot know more than 500 men at all well; you cannot know intimately more than about 25 or 50. Some system will therefore have to be devised to permit individual intimacy between superintendents and their workmen.

The psychologists are making a pretty broad claim, but in a measure it is being substantiated, notably in the Army. Some good helpers were needed for the commanding officer; the psychologists said they could furnish them, and they arranged some tests, proceeded to get their results, and in an hour's time they stripped the brigade of all the good men in it. Line officers then went to the Surgeon General and insisted that a special department of psychology be created. The methods now used all grew out of this test. I am told that 3000 men a month have been eliminated from the various army camps, on the basis of these tests. In connection with industry it is clear that tests should be conducted not alone for the purpose of eliminating the feeble-minded from the factories, but also for picking out men who may be most suitable for certain kinds of work.

Cases of unemployment have been found to be due roughly to three kinds of influence. The first group includes the feeble-minded persons who have gotten along pretty well, and have then gradually lost count and been thrown out. Such persons, however, still can be used. One of our former patients is now in the radio service although he is of the age of nine years mentally. I am told by a professor in an institute for the feeble-minded that he knew of 22 of his graduates in various parts

of the military service. The French make excellent reports of the utility of certain types in their army.

The second group includes those persons who suffer from a kind of disorder which leaves them normal at intervals; these may be called the "moody" people. These men are usually blue or else over-gay; curiously, these two phases form one disease, as has been proved comparatively recently. These men are sometimes very useful; they are thorough workmen if you understand them and sympathize with them, but sometimes they are very disturbing to those who are managing the job. They have to be supported more or less, and encouraged and smoothed down.

The third group includes persons whom you might call "queer" or "twisted," whose chief idea is that they are being persecuted. Sometimes they are very good workmen, but I should suppose that such a person would not work so satisfactorily on a two-man drill as with a one-man drill. These persons are generally hated by the other workmen, but are commonly liked by their foremen because they are good workmen and are often inclined to exercise espionage—sometimes on the company and sometimes on the men.

If these views are correct—and I think they are—more investigation ought to be done on this line. If the health of workmen in mines and factories can be improved thereby, we should always be willing to go a long way. If a big mining company were to employ a physician who knew something about mental diseases, so that these temperamental types could be recognized, identified, and segregated in such a way as to be of most value to the company and to themselves, much good could certainly be accomplished along this line. I will warrant that a little research of that sort, carried on for three or four years, would bring great results.

The I. W. W. might be called a vehicle for those of the passive voice. Their aims and their powers are in the passive voice and they cannot get out of it. They are dissatisfied—chronically so—no matter what they have or what they are doing; it is a habit of theirs, and they cannot get away from it, not even if they get to be president of a company. This type often includes men of brains; but still they are in the passive voice and will remain in this phase; to them, other people are just secondary. There are some of this type who really try to accomplish something; sometimes the I. W. W. is the only available vehicle for them to exercise their ambition and what energy they have. They should be encouraged by being urged to join a trade union, or by some other means, to exercise their energy in the right direction. Encourage them to look up to some one of their number who is intelligent and in whom they have confidence; you will then be able to treat with this leader instead of having to treat with them collectively or as individuals. Try to get them into the active voice and away from the influence of the I. W. W. leader, who never will assimilate, because he is deluded by persecution and is perennially dissatisfied.

J. E. JOHNSON, JR.—Up to 15 or 20 years ago, conditions in many steel mills, in regard to the safety of employees, were little short of criminal; men were killed because the general superintendent did not care whether they were killed or not. I believe that the Illinois Steel Company was one of the first to realize that their previous attitude was

morally bad and financially unprofitable. They set about correcting those conditions, and after many years reached the point of employing a safety director. We have with us one who has given a great deal of attention to the coördination of labor and employment problems—Mr. Young.

A. H. YOUNG.—The problem is not whether we ought to coördinate the various activities of labor, but how to do it, and this is going to require a lot of thought and intelligent handling.

First let us consider the employment manager, whose function is the employment and distribution of the men. His first problem is to study the desirable labor supply and his second, is the selection of employees from the applicants. A third activity of the employment manager is to keep a record of the services of each employee. This should include his date of employment, changes in his occupation and the reason therefor, disciplinary or merit marks, as well as the reason for his discharge, when it comes, and the conditions and circumstances surrounding it. There should also be a record of his participation in various coöperative schemes. This statistical data should all be analyzed to such an extent as to show the number of foremen under whom a man has worked, his different occupations and their locations, and the length of his service.

Next, as to the medical service. The doctor can be of great practical utility to an employer, by detecting and segregating all incipient defects, such as deficiency in sight or hearing, as well as the communicable diseases and tuberculosis. In some industries, physicians have served as a bond between the men and the management. By wise counsel at a time when the employee is very appreciative the physician establishes a contact which is very valuable both to the men and to their employers. Dental and orthopedic clinics, also, are very important adjuncts in the maintenance of health. The visiting nurse, likewise, is in a peculiarly advantageous position to render service and promote good feeling between the men and the company.

The problem of shop sanitation has developed the sanitary engineer, who has supervision over the condition of the toilet rooms, the lockers, the drinking-water system, and other features, including the establishment of industrial kitchens, where the men can eat their lunch in cleanliness and have hot coffee or chocolate.

The illuminating engineer is another recent development. It is his province to care for the proper lighting of the factory and to provide all the natural light possible. The importance of proper lighting, as relating to safety, is readily appreciated. Similarly, the fire prevention engineer is expected to reduce the fire hazard to a minimum, thus preventing loss of time and possible personal injuries. The air-conditioning problem, likewise, has brought out the ventilating engineer, whose province is to control the temperature and humidity of the air.

In connection with large companies will also be found the athletic instructor, the playgrounds director, the educational director, the librarian, and a host of other new officials. One large industrial establishment has an auditorium seating 1500 people, and, on one day each week, sends all its employees there for an hour or more to listen to general lectures of educational value. Inspection of other plants and other industries by groups of the workmen is a desirable feature. Classes for foremen a

sometimes conducted. For the families of the employees many companies have instituted domestic science studies and kindred courses.

The housing problem embraces the construction and maintenance of dormitories and camps. Many companies own houses which are let out to the men at moderate rentals, depending upon the low rents to keep the men steadily at work; on the other hand, some companies are seeking to instill into the men the desire to own their homes.

Lastly, we find the safety engineer. Among his duties are periodical inspections, and the teaching of safety ideas to every new employee. The men are encouraged to study safety and devise new safety rules and plans. To this end, we institute prize and bonus plans.

In all organized effort to better the conditions of the men, the suggestion of charity should be avoided; that is, the men should be encouraged to think that these measures are something that they are entitled to. I have not mentioned the word "welfare" tonight, because I know from experience that if you put all these activities under the word "welfare," it smacks of paternalism.

The foreman represents the management to the men; he is their immediate superior, and he should, in all cases, be a man in whom the employees will have confidence and respect. His selection is altogether too frequently a matter of indifference. His remuneration, likewise, is often not compatible with his importance. A good foreman, efficiently going about his business, will nearly always be able to present to the company any of the complaints and dissatisfactions of the men, and the company can then take steps necessary to remedy these objectionable conditions; this can be done in a conciliatory spirit and just a little in advance of the critical period, through the observations and efficiency of the foremen.

I cannot too strongly emphasize the importance of paying closer attention to the selection of foremen, with a view to their relations with the men under them. They should be taught the true principles upon which our industries stand—what you men of affairs are trying to accomplish; and you will never attain efficiency until the men know what you are trying to do, which demands the intelligent and generous coöperation of your foremen.

After a unanimous vote of thanks for the speakers of the evening, the meeting adjourned.

Meeting of April 23, 1918

The April meeting was held on Apr. 23, with about 35 members in attendance. The meeting was preceded by a dinner.

The report of the committee appointed by the Chairman to consider matters of price-fixing and taxation, as they affect the mineral industry, and to recommend to the Section an outline of the principles which the Section might urge Congress to adopt, was first considered. A motion was unanimously carried that a vote of thanks be extended to Messrs. J. Parke Channing, C. F. Kelley and J. V. N. Dorr, the members of the committee, for their very careful and painstaking report. [The length and complicated nature of this report preclude its reproduction here; copies may be obtained on application to the Secretary of the Institute.]

Dr. L. D. Ricketts then displayed four reels of motion pictures showing the operations at the New Cornelia Copper Company's property at

Ajo, Ariz. Dr. Ricketts first gave a general outline of the work, and then added comments as the pictures were thrown on the screen, thus adding greatly to the value and pleasure of the evening.

A. D. BEERS, *Acting Secretary*.

SAN FRANCISCO SECTION

A. C. LAWSON, *Chairman*,

ROY H. ELLIOTT, *Vice-chairman*,

W. H. SHOCKLEY, *Sec'y-Treas.*, 959 Waverly St., Palo Alto, Cal.

T. A. RICKARD,

C. F. TOLMAN, JR.

Twenty persons were at the meeting of the Section on Apr. 2, 1918, and fifteen were at the Engineers' Club dinner that preceded the meeting.

The paper of the evening was the "Fundamental Principles of Flotation" by W. H. Coghill, of the Seattle Station of the U. S. Bureau of Mines. Before the dinner, Mr. Coghill secluded himself in an inner room and requested that he remain undisturbed; this mysterious proceeding raised the curiosity of the guests and their curiosity was not lessened when the request was made that only four persons be admitted at a time and that these four keep very quiet. This procedure was necessary in order to avoid disturbing a boat-shaped piece of window-glass, about 60 by 140 mill. that was floating quietly on the surface of the water; on the glass were two corks and a lead pencil. Careful examination showed that the plate of glass rested in a depression with walls perhaps 3 mill. high. Quiet was needed for this delicate experiment; the floating of the glass was accomplished* by placing it on a pedestal and admitting the water by a siphon.

In opening his talk, Mr. Coghill said that he did not take for his text "my cup runneth over" but he took an over-filled tumbler. From a consideration of the water standing higher than the level of the glass he was led to experiment and from the experiments he concluded that the supporting of the window-glass boat is due to the dimple in which it lies; the force that supports the glass is the head of water above the level of the glass. A disk of glass about 60 mill. in diameter when floated on the water held an additional weight of 10 grams of sand.

When water is allowed to flow on glass it advances so as to make an angle of 60 deg. with the glass; this same angle is made by the surface of the water standing in a glass vessel. These angles are perfectly definite and the curve of the profile of the water has been worked out by Mr. Coghill's assistant, Mr. Anderson, who deduced as definite a formula for the profile as that for the parabola or hyperbola. Given the surface tension and the specific gravity of a liquid, its curve can be calculated accurately. The drop of water on a glass plate will have a maximum height 5.4 mill. (say 0.2 in.). More water does not increase the height of the drop, but advances the edge; when the advancing water reaches boundary of the glass plate its height rises to about 5 mill. before it flows over the side of the glass. Various beveled glass plates were used; the maximum height of the water at the edge of the glass is reached when the plate has a bevel of 60 deg., that is, the same as the angle of the advancing water. From these data is deduced that the most floatable form of a substance in water is that which has a re-entrant angle of 60 deg. It also follows that the larger the angle of contact of a substance, the better it floats. A strong

* Reformed spellings retained by special request of the Secretary of the Section.

flotation effect was obtained with aluminum wire coated with paraffin and then rolled in lycopodium powder; powdered galena had the same effect as the lycopodium powder.

Charts were shown giving the action of 22 oils; these oils were classed under two heads; first, those oils that, when present to the amount of $\frac{1}{10}$ per cent. reduced the surface tension to less than 62 dynes; second, oils that did not reduce the surface tension to 62 dynes under the same conditions. The maximum effect was to reduce the surface tension to 45 dynes. It seems likely that surface tension tests on mill solutions may give us a practical method of testing various oils; this test could be made in from 15 to 20 minutes. The drop-weight test is useful. Most of the oils can be classed as insoluble, unless they are emulsified.

The theory that a bubble of insoluble oil is formed and carries up the mineral seems doubtful. Mr. Coghill questioned the existence of these oil bubbles; in the Callow cell, tho millions of bubbles are ascending, yet on arriving at the top of the liquid they burst—where does the oil go?

James M. Hyde complimented Mr. Coghill's quantitative data. With regard to the query as to what becomes of the oil carried up by the oil bubbles, Mr. Hyde found that when a flotation apparatus has been run for a long time heavy oil accumulates and must be removed. He has sometimes wondered if flocculation is a factor; when working with a machine having a glass front, so that the operation could be seen, it was noticed that a time came when thru the plate could be seen the pale colored gangue with dark streaks in it; this the operators called the "clean-up."

Other discussion followed, in which the Messrs. A. C. Lawson, T. A. Rickard, L. H. Duschak and E. A. Hersam participated.

W. H. SHOCKLEY, *Sec.-Treas.*

SOUTHERN CALIFORNIA SECTION

RALPH ARNOLD, *Chairman*, W. F. STAUNTON, *Vice-chairman*,

A. B. CARPENTER, *Sec'y-Treas.*, 530 Citizens National Bank

A. B. W. HODGES,

LESLIE C. MOTT,

C. COLCOCK JONES,

JAMES W. NEILL.

The annual dinner and meeting of the Section was held at the Sierra Madre Club on the evening of May 6. Thirty-one members of the Section were present.

After the dinner, Chairman A. B. W. Hodges opened the meeting and after reading a telegram from President Jennings, regretting that he could not be present, he introduced Mr. W. O. North, Assistant Superintendent of the United Eastern Mining Co. at Oatman, Arizona. Mr. North gave a talk on the Modern Milling Methods for Gold Ores, as practised in the Company's new mill. He covered particularly the recent changes in the milling practice at this plant, and the reason for such. The discourse was informal in its nature, but was replete with valuable data on a subject of importance to all present. Following the discussion, which was generally participated in by the members present, the Chairman introduced Mr. Bernard MacDonald.

Mr. MacDonald presented a preliminary paper on a subject of particular interest to producers of silver by the cyanide process, at the

present time. The subject of the paper was "A Reverberatory Furnace for the Smelting of Silver Cyanide Precipitate." Detail drawings were shown and the construction of the furnace described. Mr. MacDonald stated that this furnace had been installed and was being successfully operated at Pachuca, and Guanajuato, in Mexico, with apparently a great saving in cost over the cyanide method. This radical departure from the recognized practice was of great interest and created an active discussion, some points of which could not be completely answered owing to the short time since this class of furnace has been operated. More data are being assembled and at an early date Mr. MacDonald will submit a complete paper for publication.

The secretary then introduced the subject that has recently been before many of the Sections, viz., the advisability of changing the name of the Institute to the American Institute of Mining and Metallurgy. The arguments pro and con as printed in the May Bulletin were read and a number of the members present spoke on the subject. An informal vote was finally taken and all but three of the thirty-one members present were opposed to any change of name.

At the annual meeting which followed, the reports of the Secretary-Treasurer were read, audited, and approved. The sealed ballots for officers for the ensuing year were opened by a committee, who reported the election of the officers and executive committee listed above.

After a vote of thanks to the retiring officers had been moved and carried, the meeting adjourned.

ALVIN B. CARPENTER, *Secretary.*

TULSA SECTION

ALF. G. HEGGEM, *Chairman,*

M. M. VALERIUS, *Junior Vice-chairman*

ALEXANDER DEUSSEN, *Vice-chairman,*

CHARLES H. TAYLOR, *Vice-chairman,*

ERASMUS HAWORTH, *Vice-chairman,*

JAMES H. GARDNER, *Secretary-Treasurer, Tulsa, Okla.,*

IRVING PERRINE,

J. J. RUTLEDGE,

S. H. WORRELL.

The organization meeting of the Tulsa (Oklahoma) Section of the Institute was held in the assembly room of the Tulsa Chamber of Commerce on February 25. The meeting was well attended and various matters were enthusiastically discussed. Letters of authority from the Board of Directors granting the local section were read and the opportunities and advantages surrounding it for war service, etc., were brought out, especially in regard to petroleum and its derivatives. A set of by-laws was adopted and the officers and executive committee listed above were elected for the ensuing year.

Preparations are under way for a rousing meeting in September, and several papers have already been offered for that occasion. At that time we hope to have as our guests the President and Secretary of the Institute. Everything considered, the Tulsa section is well under way to a permanent and useful existence in this portion of our country.

JAMES H. GARDNER, *Secretary-Treasurer.*

OTHER SOCIETIES]

MINING AND METALLURGICAL SOCIETY OF AMERICA

San Francisco Section]

The San Francisco Section of the Mining and Metallurgical Society of America held a joint meeting with the local section of the American Institute of Mining Engineers at the Engineers' Club, San Francisco, on Tuesday, Apr. 16, 1918. The meeting was preceded by a dinner. Letters from the parent body in New York asking for the consideration of the proposed bill before Congress, and an expression of opinion relative to the appointment of a Federal Administrator of Mines justified the joint meeting of the local sections of the two mining societies, in that a more representative opinion of the engineers of California could be obtained. The meeting was called to order at 7:15 p. m. by Mr. Frank H. Probert acting as Chairman. About thirty engineers were present.

Mr. Probert read a letter of March 14, from Secretary Huntoon, asking that the meeting be called. He read excerpts from *Bulletin* 117 of February 28, 1918, of the Mining and Metallurgical Society containing a copy of the proposed bill, so that all present might be advised of its essential contents. He briefly commented on the urgent need of such legislation and invited discussion of the subject.

After long and thorough discussion on the part of the members present, Professor Lawson made the following motion:;

I move that a resolution expressing the sense of the joint meeting of the local sections of the American Institute of Mining Engineers and Mining and Metallurgical Society of America be forwarded to the secretaries of the two societies to the effect that we heartily approve of the purpose and intention of the bill designed to promote and stimulate the production of minerals necessary for the successful prosecution of the war; and that we suggest prices should be fixed for the period of the war and two years thereafter, and that these prices, guaranteed by the Government, should apply at the nearest shipping point to place of production of the minerals.

This motion was carried. The meeting then adjourned, and a telegram was sent by Mr. Probert, the Chairman, to Mr. Huntoon, notifying him of the motion that had been carried at the meeting.

AFFILIATED STUDENT SOCIETIES

LEHIGH UNIVERSITY

On April 25, the Mining and Geological Society of Lehigh University held a meeting and elected the following officers for the college year 1918-1919:

C. S. SCHUBERT, *President*,

C. G. GILMAN, *Vice-president*,

H. TSAI, *Secretary*,

E. D. HOLLINSHEAD, *Treasurer*,

C. N. TOMLINSON, A. A. KORVES, *Curators*.

After a short business meeting the Society was favored by three interesting and instructive talks. Mr. C. A. Bonine spoke on the "U. S. Geological Survey" and showed a number of beautiful lantern slides; Mr. R. Rosenbaum read a paper on "Geodes;" and Prof. B. L. Miller presented a brief discussion on "War Minerals."

H. TSAI, *Secretary*.

THE UNIVERSITY OF MINNESOTA

The annual election of officers of the School of Mines Society for the ensuing year, 1918-1919, was held on Apr. 27, 1918, with the following result:

JOSEPH O. HOSTED, *President*,

WALTER R. MELLEM, *Vice-president*,

JAMES D. WHEELER, *Secretary-treasurer*,

C. HENRY CHADBURN, *Editor*,

EDWIN N. CARLSON, *Assistant Editor*.

Messrs. E. A. Sporley and J. Mathews, in charge of Mine Rescue Car No. 7, of the Lake Superior District, have just completed two weeks' instructional work in mine rescue and first aid at the Minnesota School of Mines Experiment Station.

The following lectures were given before the Minnesota School of Mines Society during the year 1917-1918:

War Minerals.....	Dr. William H. Emmons.
Bureau of Mines Experiment Stations.....	Dr. Dorsey A. Lyon.
Manganese Problem.....	Edmund Newton.
The Students in War Times.....	President Marion L. Burton.
Industrial Russia.....	Professor William H. Sternberg.
Scientific Exploration, also one day's demonstration of diamond drilling and bit setting.....	E. J. Longyear Exploration Company.
	H. K. ARMSTRONG, <i>President</i> , 1917-1918.

NEWS FROM MEMBERS AT THE FRONT

Stanley C. Bullock, Captain, Royal Engineers, has been awarded the Military Cross.

Charles L. Cantley was commissioned Lieutenant in the Fifth Royal Highlanders of Canada and went to France with the first Canadian contingent early in 1915, being Quartermaster of the Battalion. He went through the second battle of Ypres, Festubert, St. Eloi and the other engagements in which the Canadians were engaged up to July, 1915, at which time he was promoted to the rank of Major. He was later ordered home by General Sir Sam Hughes, then Canadian Minister of War, and his services were loaned to the Nova Scotia Steel & Coal Co., suppliers of shell steel and forgers of shells in Canada. He continued with this company as chief officer in charge of munitions until the latter part of 1917, when he sailed for England with his old regiment.

John D. Cooner was wounded on Apr. 9, 1918, by shrapnel, and is now in a hospital in Paris. He is getting along nicely.

T. C. Gorman was killed in action in France on Mar. 18, 1918.

Thayer Lindsley received a commission as Captain of Heavy Artillery upon completion of a course at Fortress Monroe, and sailed for France the latter part of 1917. Upon the completion of a further course with the French heavy artillery, he was appointed instructor at a new training center.

J. G. Ross was commissioned a Lieutenant in the Royal Highlanders of Canada and went "Over There" with the first Canadian contingent as officer in charge of the Machine-gun Section of the 13th Canadian Battalion, Royal Highlanders. At the second battle of Ypres, April, 1915, he was promoted on the field to the rank of Captain, and appointed Adjutant of the battalion. At the battle of Festubert, May 20, 1915, he received a shell wound which smashed one leg, sending him to the hospital for a year. In February, 1916, owing to physical disability from wounds, he was honorably discharged from the Canadian Army, and is now practising his profession of consulting mining engineer.

Edward H. Perry, 1st Lieut., Co. D, 6th Regiment of Engineers, A. E. F., was killed in action on Mar. 30, 1918.

MEMBERS OF THE INSTITUTE IN MILITARY SERVICE

(The following list contains the names of those members of the Institute of whose connection with military service we have only recently become acquainted; it also includes the names of a few who have recently been promoted or transferred, indicated by a *. A complete list was published in the Year Book, issued as a supplement of the *Bulletin* for March, 1918.)

*AMBLER, HARRY A., 1st Lieutenant, O. R. C., 30th Infantry, A. E. F.
BAKER, R. F., Private, Intelligence Section, Headquarters 90th Division.

*BARTON, L. A., Captain, 604th Engineers.

*BATTEN, H. L., Lieutenant, Canadian Engineers, C. E. F.

*BENSEL, J. A., Major, U. S. Reserves.

BIRKETT, HOWARD, Lieutenant, Aviation, U. S. Signal Corps.

BLOOMFIELD, E. C., Lieutenant, 1st Canadian Tunnelling Co.

BOOTH, L. E., Watertown Arsenal, Det. E. O. C., N. A., Watertown, Mass.

*BOWMAN, REGINALD G., 1st Lieutenant, Engineers, U. S. R., Int. Ord. Dept. No. 4, A. E. F.

*BRADLEY, CLARENCE I., Convois Automobile Section 585, S. S. U., P. A. R., B. C. M.

BRIBER, F. E., Co. D, 314th Engineers, 89th Division.

BROOKS, FLOYD R., Lieutenant, Engineers Training Depot, St. Johns, P. Q., Canada.

BROWN, W. SINCLAIR, Department, Aeronautical Supplies, Air Board Offices, Swansea, England.

*BULLOCK, STANLEY C., Captain, Royal Engineers. (Awarded Military Cross.)

*BURNS, J. J., Co. 1-B, E. R. O. T. C.

*CANTON, WILLIAM R., Battery A, 62d Regiment, C. A. C.

*CARROLL, WALTER, 108th Ordnance Depot Co.

*CHAPMAN, IRVING A., Ensign, U. S. Submarine Base, New London, Connecticut.

*COHEN, MAXWELL B., Meteorological Section, A. and M. College, Texas.

COPELAND, N. R., Lieutenant, Camp Dick, Dallas, Texas.

CORSA, DEAN, Captain, Co. D, 512th Engineers, A. E. F.

*CURTIS, FRED S., Captain, Engineer Reserve Corps, U. S. P. O. No. 701, 17th Engineers.

CUSHING, DANIEL, Metallurgist, U. S. Signal Corps.

DAVIS, THORNTON, 1st Lieutenant, 13th Field Artillery, A. E. F.

DOBSON, PERCY G., Canadian Army.

DODGE, CLEVELAND E., Lieutenant, 304th Field Artillery, A. E. F.

*DOENNECKE, H. W., Corporal, Foreman of Poison Gas Plant, Ordnance Department.

*DOWNES, FRANK A., 2d Lieutenant, 535th Engineers.

EDWARDS, JOHN R., Rear-Admiral, U. S. N., Brown University, Providence, R. I.

ESTABROOK, W. H., Captain, 3d Battalion, 20th Engineers, A. E. F.

FARRAND, I. W., Sergeant, Co. A, 27th Engineers, A. E. F.

FELTON, CORNELIUS C., Co. G, 35th U. S. Engineers, A. P. O. 735, A. E. F.

FOESTER, HALLARD, Officers' Training School, Camp Lewis, Washington.

GARRISON, MURRAY E., Flying Cadet, Squadron A53, Aviation Barracks, Berkeley, California.

GIROT, PIERRE, Captain, 22d Regiment, F. A., French Army.

GORE-LANGTON, C., U. S. Engineers, Special Service, France.

GREENE, LEWIS H., Commanding Officer of Motor Supply Train 413.

GREENAN, J. O., Headquarters Co., 27th Engineers.

*HALLORAN, WILL, Battery A, 146th F. A., 41st Division, A. E. F.

*HARMS, P. L., Captain, 29th Co., 3d Infantry Replacement Regiment.

*HERR, L. B., JR., 1st Lieutenant, Headquarters Anti-aircraft Service, A. P. O. 728, A. E. F.

*HINES, P. R., 1st Lieutenant, Co. C, 318th Engineers (Sappers).

JOHNSTON, FRED LUCIAN, Area Engineers, Construction of the U. S. Nashville Smokeless Power Plant.

*KINNEY, S. P., Chemical Service Section, American University, Washington, D. C.

*KROGH, ALVIN T., Sergeant, Chemical Service Section, N. A.

*LANDERS, WILL H., Engineer Officer, Camp No. 20, A. P. O., No. 705, A. E. F.

LEGGE, FRED H., Construction Engineer, Quartermaster Corps, U. S. Army.

*LEWIS, WHITNEY, 2d Lieutenant, U. S. R., care of U. S. Geological Survey, Springfield, Ga.

*LIDDELL, DONALD M., Captain, A. S. Signal R. C., New York District, Grand Central Palace, New York, N. Y.

LIDVALL, E. R., Co. A, 27th Engineers, A. E. F.

*LINDSLEY, HALSTEAD, Major, Ordnance Department.

*McCLELLAND, JAMES F., Editor in Chief of the Specification Section, Equipment Division, Bureau of Aircraft Production, 9th and F. Sts., N. W., Washington, D. C.

McDONALD, JOHN A., Ordnance Corps, Filling Plant, Detachment E, Edgewood, Md.

*MEAD, RICHARD, Battery C, 101st Field Artillery, A. E. F.

MEYERS, WILLIAM R., 1st Lieutenant, Engineers Reserve Corps.

MOSES, PERCIVAL SNEED, 1st Lieutenant, National Army, A. E. F.

*NEALE, LAURENCE I., 1st Lieutenant, Co. I, 168th Infantry, A. E. F.

NESBIT, MILLARD F., Military Service.

NORRIS, R. VAN A., E. R. O. T. C., Camp Lee, Virginia.

*PERRY, EDWARD H., 1st Lieutenant, Co. D, 6th Regiment Engineers, U. S. Expeditionary Forces, France. (Killed in Action, March 30, 1918.)

*PETERSON, O. P., Aviation Repair Depot, Speedway, Indianapolis.

ROBERTS, WILLIAM PAXTON, 1st Lieutenant, Field Artillery, A. E. F.

ROBERTSON, FITCH, Aviation Mechanic, 133d Aero Squadron.

ROUSH, G. A., Supervisor of Training, Inspection Division, Ordnance Department.

SAEGER, C. MARSHALL, Mechanic, 8th Co., 2d Battalion, 154th Depot Brigade.

*SMULLEN, C. KENNETH, Lieutenant, Aeroplane Observer for Heavy Artillery.

- ***SNEDAKER, EUGENE C.**, 1st Lieutenant, Co. D, 4th U. S. Engineers,
A. E. F.
SPICKARD, HAROLD E., 7th Engineers Train, France.
STIFEL, CARL G., Private, Engineer of Tests, U. S. O.
***WAITE, H. M.**, Lieutenant-Colonel, Railway Transportation Corps,
A. E. F.
WHITE, CLARENCE B., Metal Expert, Quartermaster General's
Office, Ordnance Department.

PERSONAL

The following is an incomplete list of members and guests who called at Institute headquarters during the period May 10, 1918 to June 10, 1918.

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| Arthur K. Adams , Potrerillos, Chile. | J. M. Mahoney , Wilkinsburg, Pa. |
| John Carter Anderson , Tucson, Ariz. | Benjamin L. Miller , South Bethlehem, Pa. |
| George S. Blair , Camp Gordon, Ga. | Wilbur A. Nelson , Nashville, Tenn. |
| W. A. Deane , Summitville, N. Y. | Miles G. Nixon , Chicago, Ill. |
| Charles H. Fulton , Cleveland, Ohio. | Walter G. Perkins , San Francisco, Cal. |
| Rudolf Gahl , Inspiration, Ariz. | G. M. Ponton , Ottawa, Canada. |
| C. C. Griggs , Eureka, Utah. | D. A. Powell , Columbus, Ohio. |
| J. F. Hanst , Potrerillos, Chile. | H. W. Reed , Salt Lake City, Utah. |
| Stanley C. Herold , Pittsburgh, Pa. | J. C. L. J. Seelig , Padong, East Indies. |
| Floyd D. James , Boston, Mass. | Oberlin Smith , Bridgeton, N. J. |
| Charles Janin , San Francisco, Cal. | Harrison Souder , Cornwall, Pa. |
| E. Horton Jones , Copper Cliff, Ont. | Stanley A. Spellmeyer , Camp Meade, Md. |
| William Kelly , Vulcan, Mich. | Roger S. Sperry , Waterbury, Conn. |
| Ichiro Kitsunezaki , Tokyo, Japan. | D. R. Thomas , Toronto, Canada. |
| P. K. Lucke , San Antonio, Tex. | Thor Warner , Phoenix, Ariz. |
| E. Francis McCrossin , Birmingham, Ala. | |

L. Douglass Anderson, formerly superintendent of the United States Smelting Co., Midvale, Utah, is now manager of smelters, Intermountain District, United States Smelting, Refining & Mining Co., Salt Lake City, Utah.

D. W. Brunton has been elected a member of the Naval Consulting Board.

Charles Y. Clayton is now with the Bureau of Mines, Pittsburgh, Pa.

William N. Fink is now connected with the Cusi-Mexicana Mining Co., Apartado 125, Chihuahua, Mexico.

H. W. Foester has resigned as assistant manager of the Tigre Mining Co., Esqueda, Sonora, Mexico, to enter the Fourth Officers' Training Camp.

G. Murray Gillette has been transferred from the position of manager of the Elkhorn Division of The Consolidation Coal Co., to manager of the Maryland Division of the same company at Frostburg, Md.

Ira L. Greninger is now mine superintendent, Andes Copper Mining Co., c/o Barreas & Co., Agents, Casilla 230, Antofagasta, Chile.

William S. Hall is now with the Chino Copper Co., Hurley, N. M.

F. H. Franklin Hampton has accepted a position as engineer, Fortuna Nitrate Co., Ltd., Oficina "Celia" Carmen Alto., Antofagasta, Chile, S. A.

J. F. Hanst, formerly of the Cleveland-Cliffs Iron Co. and latterly chief mining engineer for the Andes Copper Mining Co. at Potrerillos, Chile, has returned to the United States.

William H. Hubbard, Jr. has resigned his position with The Balbach Co. to take a position as engineer of the Northport Smelting & Refining Co., Northport, Wash.

Royal P. Jarvis has resigned his position with the Cananea Cons. Copper Co., Cananea, Mexico, and is now with the Cia. Metalurgica de Torreon, Apartado Postal No. 93, Torreon, Coah., Mexico.

John H. Klepinger, for the past four years superintendent of the B. & M. Reduction Works of the Anaconda Copper Mining Co., has resigned his position and retired from the service of the company.

William Korotkin has accepted a position in the engineering department of the Burro Mountain Branch, Phelps-Dodge Corporation, Tyrone, New Mexico.

Arthur L. Lee has resigned his position with the Homestead Iron Dyke Mines and is now engineer for the Electric Point Mining Co., Leadpoint, Wash.

E. P. Mathewson has accepted a position with the American Smelting & Refining Co., 120 Broadway, New York, N. Y.

Arthur H. Meyn is now salesman, Detroit Steel Products Co., 68 Post Street, San Francisco, Cal.

Wilbur A. Nelson was elected State Geologist at the meeting of the Tennessee Geological Commission held April 9. Mr Nelson, who was formerly an assistant on the Tennessee Geological Survey, has for the past several years been engaged in private work and in mining barytes and manganese in Cartersville, Georgia. He was prevented from assuming actual charge of the Survey until May 1 on account of his mining and other affairs. He comes to the Survey with a knowledge of the State's mineral resources and the possibility of their future development that will stand him in good stead in continuing the State Survey on the high plane on which it has always been maintained.

Maynard Nizel is now connected with the Air Nitrates Corporation, Mussel Shoals, Ala.

James M. Platt has accepted a position as assistant to manager, Sociedad Esplotadora de Caylloma Consolidado, Casilla 180, Arequipa, Peru, S. A.

John C. Scoles has accepted a position as mining engineer, Mines Efficiency Co., 708 Alworth Bldg., Duluth, Minn.

John B. Stewart is now with C. L. Constant Co., Royal Bank of Canada Bldg., altos, Dpto. No. 3, Santiago de Cuba, Oriente, Cuba.

W. E. Thomas is now superintendent, Cia. Minerales y Metales, S. A., Cerralvo, N. L., Mexico.

Robert T. Walker has accepted a position as superintendent of the Virginia-Louise Mining Co., Pioche, Nev.

Torrey H. Webb, Lieutenant Aviation Section, Sig. R. C., has been carrying the mail by aeroplane between New York and Washington. He made a very successful flight to Boston on Thursday, June 6, but met with a slight accident in alighting. He made the trip in 3 hr. 18 min., lapsed time between points, but had to alight once on account of fog and rain to get his bearings.

Albert E. Wiggin has been transferred to Great Falls, as general superintendent of the Smelter Hill, Boston & Montana Reduction Dept.

POSITIONS VACANT

Draftsman and transitman for coal-mine work in middle West. Salary \$125 per month. No. 277.

Surveyor and mine sampler for development company in Mexico. Applicant must be willing to interest himself in mine sufficiently to act as assistant to the superintendent and be able to take charge in case the superintendent should be incapacitated at any time. No. 326.

A copper company in Mexico desires services of engineer to act as chief chemist and flotation operator. No. 327.

Instructor in mining and metallurgy, the work being chiefly in mining for college in middle West, to start Dec. 1. Salary \$1200 to \$1400. No. 328.

A copper company in Mexico is increasing its force of underground foremen and desires the services of two men competent to act as assistant underground foremen. Chances for advancement excellent. Knowledge of Spanish is required. Salary to start \$200 per month. No. 329.

Young man for core-drill work for coal company. No. 330.

ENGINEERS AVAILABLE

(Under this heading will be published notes sent to the Secretary of the Institute by members or other persons introduced by members.)

Experienced mining engineer, Columbia School of Mines graduate, practical experience in drifting, shaft sinking and development work, also in mining, operating and equipping iron, copper and zinc properties. Married, age 32, available at once. Open for position as superintendent or assistant. No. 462.

Member, mining engineer, age 39, married, technical graduate, 12 years' experience in gold mining and milling; past four years as superintendent of large properties. At present employed but open for engagement after July 1; will consider no position not offering a future. Salary \$4800. No. 467.

Member, mining engineer, age 46, married, desires a position as superintendent, or an opening with an industrial company of permanency. Western and Alaskan experience in mining, cyanidation and concentration. At present manager of an Eastern property, but desires a change. Available on thirty days' notice. No. 468.

FORTHCOMING MEETINGS OF SOCIETIES

Organisation	Place	Date 1918
American Chemical Society.....	Cleveland, O.	Sept.
American Society of Sanitary Engineers.....	Chicago, Ill.	Sept.
National Petroleum Association.....	Atlantic City, N. J.	Sept.
American Institute of Mining Engineers.....	Colorado	Sept. 2-7
National Association of Stationary Engineers.....	Cincinnati, O.	Sept. 9-13
Association Iron, Steel, Electrical, Engineers.....	Baltimore, Md.	Sept. 9-14
British Iron and Steel Institute, Autumn Meeting	London, Eng.	Sept. 12-13
National Exposition of Chemical Industries.....	New York, N. Y.	Sept. 23-28
American Electrochemical Society.....	Princeton, N. J.	Sept 30- Oct. 2
Institute of Metals Division, A. I. M. E.....	Milwaukee, Wis.	Oct. 8-11
Iron and Steel Members, A. I. M. E.....	Milwaukee, Wis.	Oct. 8-10
American Foundrymen's Association.....	Milwaukee, Wis.	Oct. 7-12
American Museum of Safety and Sanitation, Exposition.....	St. Louis, Mo.	Oct. 7-12
National Safety Council.....	St. Louis, Mo.	Oct. 14-17
Business Show.....	New York, N. Y.	Oct. 21-26

PUBLICATION NOTES

INDEX TO TRANSACTIONS

After a delay of many months, which is very much regretted, but which, it is hoped, will be one means of insuring a volume of accuracy where accuracy is very important, the Institute now has for distribution copies of the index of Volumes XXXVI to LV, inclusive. This is more than a mere index of names of authors and titles of papers. Every important topic under consideration by author or discussor is introduced under such key-word as will enable an engineer to locate the desired information with the minimum expenditure of time. This index sells for \$5* in half morocco binding and \$4* in paper covers. With the index of Volumes I to XXXV (which sells for \$5 in half morocco and \$4 in paper covers), it forms a complete index of the first fifty-five volumes of the Institute's *Transactions*.

These collective indexes are very valuable to members of the Institute, enabling them to look up matters in their own library; if they have the volumes to which the indexes refer, they can get the information at once, and, if not, they can readily determine whether or not a visit to a nearby public library is desirable.

TRANSACTIONS WANTED

The Institute's stock of Volumes XXXI, LI, and LII has become much reduced by sales. If members have copies of these volumes which they can spare, the price of \$3 per volume will be paid for them, if in good condition. We shall appreciate it if members will pass the word along.

* These prices were incorrectly quoted in the June *Bulletin*.

LIBRARY

AMERICAN SOCIETY OF CIVIL ENGINEERS

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

AMERICAN SOCIETY OF MECHANICAL ENGINEERS

AMERICAN INSTITUTE OF MINING ENGINEERS

UNITED ENGINEERING SOCIETY

HARRISON W. CRAVER, DIRECTOR

The library of the above-named Societies is open from 9 A. M. to 10 P. M. except on holidays. It contains about 70,000 volumes and 90,000 pamphlets, including sets of technical periodicals and publications of scientific and technical societies.

Members of the Institute, with few exceptions, are forced to spend a portion of their time in localities isolated from sources of information. To these the Library, through its Library Service Bureau, can render valuable service through correspondence; letters requesting information will receive especial attention. The Library is prepared to furnish references and photographic copies of articles on mining and metallurgical subjects; to determine the existence of mining maps, and to furnish general information on the geology and mineral resources of all countries.

All communications should be made as definite as possible so that the information received may be what is desired and not include collateral matter which may not be of interest. The time spent in searching for such collateral matter will be saved, and the information will be sent more promptly and in more usable shape.

Library Accessions

INCOMPLETE LIST CLASSIFIED BY SUBJECTS

Mining

- ALASKA. Report of the Mine Inspector for the Territory, for the year ended June 30, 1912. Washington, 1912. (Gift of U. S. Bureau of Mines.)
- ALASKA. Mine Inspector. Report 1913-1914. Washington, 1914. (Gift of U. S. Bureau of Mines.)
- MINING AND QUARRY INDUSTRY OF NEW YORK STATE. Albany, 1918. (Gift of N. Y. State Museum.)
- MINING INDUSTRY IN THE TERRITORY OF ALASKA DURING 1915. Washington, 1917. (*Bull.* 142, Bureau of Mines.) (Gift of U. S. Bureau of Mines.)
- SOUTH DAKOTA. State Inspector of Mines. 28th Annual Report, 1917. Lead, 1917. (Gift of State Inspector of Mines.)
- WASHINGTON. State Mine Inspector's Annual Report of Coal Mines, 1917. Olympia, 1918. (Gift of Washington State Mine Inspector.)

Geology and Mineral Resources

- EARLIER MESOZOIC FLORAS OF NEW ZEALAND. (New Zealand. Geological Survey. Paleontological Bulletin No. 6). Wellington, 1917.
- GEOLOGY OF CUBA. By Pablo Ortega. Habana, 1918. (Gift of Secretaria de Agricultura.)

- MARCOU'S GEOLOGICAL MAP OF THE UNITED STATES AND BRITISH PROVINCES OF NORTH AMERICA. 1853. (Gift of W. F. B. Rouquette.)
- GEOLOGY OF JACKSON COUNTY. (Missouri Bureau of Geology and Mines. Vol. XIV, second series.) Rolla, 1917.
- NOTES ON THE COAL AND IRON ORES OF WESTERN KENTUCKY. Caldwell, W. B., Jr. (Gift of W. F. B. Rouquette.)
- GEOLOGY OF THE OAMARU DISTRICT, NORTH OTAGO. (New Zealand Geological Survey, *Bull.* No. 20.) Wellington, 1918.
- GEOLOGICAL MAP OF INTO COUNTY, CALIFORNIA. 1917.
- MICHIGAN GEOLOGICAL & BIOLOGICAL SURVEY. Catalog and table of contents of the publications, with a list of publications of the United States Geological Survey relating to Michigan. 1838-1917.
- MINERAL RESOURCES OF MICHIGAN WITH STATISTICAL TABLES OF PRODUCTION AND VALUE OF MINERAL PRODUCTS FOR 1916 AND PRIOR YEARS. (Publication 24, Geological Series 20.) Lansing, 1917.
- SURFACE GEOLOGY AND AGRICULTURAL CONDITIONS OF MICHIGAN. (Michigan Geological & Biological Survey. Publication 25, Geological Series 21.) Lansing, 1917.

Petroleum and Gas

- BUENOS AIRES. Ministerio de Agricultura de la Nacion. Dirección General de Explotación del Petróleo de Comodoro Rivadavia. Memoria, 1916. Buenos Aires, 1917. (Gift of Leopoldo Sol.)
- OIL AND GAS RESOURCES OF KANSAS. (Kansas State Geological Survey. *Bull.* No. 3.) Lawrence, 1917.
- OIL INDUSTRY REVIEW. (The Evening Post, N. Y., March 2, 1918.) (Gift of Frank Anderson.)
- REVISION OF THE STRUCTURAL CLASSIFICATION OF PETROLEUM AND NATURAL GAS FIELDS. By Frederick G. Clapp. (Reprinted from the Bulletin of the Geological Society of America, v. 28, p. 553-602, 1917.) (Gift of F. G. Clapp.)
- STEEL DERRICKS AND DRILLING RIGS. Ed. 5. Carnegie Steel Company. Pittsburgh, 1918. (Gift of company.)

Industrial Organization

- COMMUNITY HOMES. A booklet issued for the purpose of assisting those who are giving consideration to a much discussed question, industrial homes. Cleveland, 1918. (Gift of The Hydraulic Pressed Steel Co.)
- MAYOR'S COMMITTEE ON NATIONAL DEFENSE. Report of the Committee on Industry and Employment. Dec. 21, 1917. New York, 1917. (Gift of Alfred D. Flinn.)

Miscellaneous

- COAL PROBLEM. By E. G. Bailey. (Reprinted from the J. E. Aldred Lectures on Engineering Practice, 1917-18.) Baltimore, 1918. (Gift of Bailey Meter Co.)
- SAFETY STANDARDS OF THE INDUSTRIAL BOARD—Pennsylvania Department of Labor and Industry. Lighting, operative on and after June 1, 1916. Vol. 1, no. 16. U. S. ORDNANCE DEPARTMENT. Report of the Tests of Metals and other Materials. 1915, 1916. Washington, 1917. (Gift of F. R. Hutton.)
- CLASSIFICATION FOR PYROMETRY AND PYROMETERS. By A. O. Ashman and K. C. Walker. April, 1918. (Gift of K. C. Walker.)
- PRODUCTION OF HIGH TEMPERATURE AND ITS MEASUREMENT. By E. F. Northrup. (Reprinted from the Transactions of the Faraday Society, v. 13.) (Gift of Alfred D. Flinn.)

Book Notices

Unless otherwise specified, books in this list have been presented by the publishers. The Institute does not assume responsibility for any statements made; these are taken from the preface or the text of the book.

All the books listed may be consulted in the Engineering Societies Library.

- ANALYSIS OF FINANCIAL STATEMENTS. By Richard P. Wilson and Harry J. Carpenter, Chic., La Salle Extension University. 38 pp., 4 illus., 9 × 6 in., paper. The book describes the methods and principles of such analyses, illustrating them by typical examples.

THE AUTOMOBILE REPAIRMAN'S HELPER. By S. T. Williams. N. Y., U. P. C. Book Company, Inc. 438 pp., 322 illus., 5 × 7 in., flexible cloth, \$2.50.

A pocket book for the mechanic, owner, chauffeur and student, covering every trouble likely to be found in all the standard cars, and including chapters on inspection and lubrication; drills, taps and lathes; welding; storage batteries; cylinder and piston-ring work; bearings; axle adjustments; repairing tops, mudguards, lamps, etc.

DYKE'S AUTOMOBILE AND GASOLINE ENGINE ENCYCLOPEDIA. Treating on the construction, operation and repairing of automobiles and gasoline engines; also trucks, tractors, airplanes and motorcycles. By A. L. Dyke. 7th edition, revised and enlarged, containing 515 charts, inserts, dictionary. . . . and supplements on the Ford, Packard and airplanes. St. Louis. 864 pp., illus., charts, tab., cloth, 10 × 7 in., \$3.50.

Presents in clear, simple, concise form the principles upon which gasoline engines and automobiles are built and operated. Sections are included on repairing, adjusting and driving, together with much miscellaneous information of value to automobile engineers and drivers. Over three thousand illustrations accompany the text.

THE CHEMICAL ANALYSIS OF IRON. A complete account of all the best-known methods for the analysis of iron, steel, pig-iron, alloy metals, iron ore, limestone, slag, clay, sand, coal and coke. By Samuel Alexander Blair. 8th edition. Phila. and Lond., J. B. Lippincott Company, 318 pp., 102 illus., 2 tab., 9 × 6 in., cloth, \$5.

In preparing the eighth edition of this well known handbook the entire work has been recast and the text has been largely rewritten, to include the recent improved methods.

THE COAL CATALOG. Pittsburgh, Keystone Consolidated Publishing Co., Inc. 671 pp., 90 illus., 25 maps, 12 × 9 in., cloth, \$25.

Combined with Coal Field Directory for the year 1918, containing explanatory articles on rank, usage, analysis, geology, storage, and preparation of coals, and such other information as is of value to the producer and consumer of coal, sales agencies investors in coal lands, railroads, mining engineers, geologists, colleges and universities, public libraries, etc. It presents a column or typical section of the productive formations of each coal-mining state in the Union; map of the state, showing the various mining districts or fields; description of the seams mined. List of mines operating in the various seams, including name of company. . . . List of seams producing coal suitable for each industrial purpose, etc. And including a directory of all the coal mines in the United States.

DIGEST OF PUBLICATIONS OF BUREAU OF STANDARDS. On electrolysis of underground structures caused by the disintegrating action of stray electric currents from electric railways. Prepared by Samuel S. Wyer. 1918. 96 pp., 10 × 7 in., paper. (Gift of the author.)

Summarizes, by verbatim quotations, the essentials of the extensive laboratory and field investigations on this subject which the Bureau of Standards has published up to August 22, 1918. The quotations selected have been classified, and the compiler has added editorial notes.

Copies may be procured from the Bureau of Standards, Washington, D. C.

ELECTRIC FURNACES IN THE IRON AND STEEL INDUSTRY. By W. Rodenhauser, J. Schoenawa and C. H. Vom Baur. Translated from the original by the latter and now completely rewritten. 2d edition. N. Y., John Wiley & Sons; Lond., Chapman & Hall, Ltd., 1917. 18 + 429 pp., 134 illus., 2 pl., 24 tab., 9 × 6 in., cloth, \$3.75.

A review of the electric furnaces used in iron smelting, and of the processes employed. The present edition contains minor revisions covering certain changes since 1913.

ELEMENTS OF SANITARY ENGINEERING. By Mansfield Merriman. 4th edition, revised with the assistance of Richard M. Merriman. N. Y., John Wiley & Sons, Inc.; Lond., Chapman & Hall, Ltd., 1918. 250 pp., 47 illus., 17 tab., 9 × 5 in., cloth, \$2.

A text-book intended to present the subject clearly in the smallest possible space, and to give greater prominence to fundamental principles than to details of construction and operation. The present edition has been revised, and fourteen new pages of text have been added.

THE EMPLOYMENT DEPARTMENT AND EMPLOYEE RELATIONS. By F. C. Henderschott and F. E. Weakly. Chicago, LaSalle Extension University (copyright 1918). 60 pp., 20 illus., 4 tab., 9 × 6 in., paper.

Contents: Selection of the Employee, The Labor Supply, Promotions and Transfers, Progressive Scale of Promotion Based on General Intelligence Requirements, Employee Records as a Basis for Promotion, Annual Survey of Employees, The Principle of Transfer, The Vocational Laboratory, Job Analysis, Labor Turnover, Educational and Welfare Work.

Suggestions based on methods in use by various corporations.

A HANDBOOK OF ROCKS. For use without the microscope. With a glossary of the names of rocks and of other lithological terms. By James Furman Kemp. 5th edition, revised. N. Y., D. Van Nostrand Co., 1918. 11 + 272 pp., 41 illus., 75 tab., 10 × 6 in., cloth, \$1.50.

Professor Kemp has attempted to avoid the difficulties usually met by students, by mentioning and emphasizing only those characteristics which a beginner with preliminary training in mineralogy can observe and grasp. The fifth edition has been revised and enlarged. An extensive glossary is included in the work.

METAL STATISTICS, 1918. 11th annual edition. N. Y., The American Metal Market Co. (copyright 1918). 427 pp., 6 × 4 in., cloth, 50 cents.

Tables showing production, prices, imports, exports, etc., of iron ore, coke, iron and steel products, copper, tin, lead, spelter, aluminum, antimony, silver and other metals. The statistics usually cover a number of years.

SULPHURIC ACID HANDBOOK. By Thomas J. Sullivan. 1st edition. N. Y., McGraw-Hill Book Company, Inc.; Lond., Hill Publishing Company, Ltd., 1918. 13 + 239 pp., 35 illus., 87 tab., 7 × 5 in., flexible cloth, \$2.50.

The author has collected in one volume of convenient size the chemical and mechanical data of practical value to makers and users of sulphuric acid in American industries.

PATENTING AND PROMOTING INVENTIONS. By Moïse H. Avram. N. Y., Robert M. McBride & Co., 1918. 166 pp., 8 × 5 in., cloth, \$1.50.

Written for the inexperienced inventor, this book gives sound practical advice on the proper methods of securing, protecting and promoting commercial patents.

SCIENTIFIC MANAGEMENT. A history and criticism. By Horace Bookwalter Drury. 2d edition, revised. (Studies in history, economics and public law; edited by the Faculty of Political Science of Columbia University. Vol. 65, No. 2. Whole number 157). N. Y., Columbia University, 1918. 251 pp., 10 × 6 in., paper, \$2. (Gift of Longmans, Green and Co.)

A history of the origins and development of scientific management, with a critical review of its important aspects. Brief biographies of the leaders in the movement are given, and its relation to labor is discussed.

The second edition has been largely extended and revised. The statements have been brought down to date, and the conclusions have been rewritten in a number of cases.

STRENGTH OF MATERIALS. A comprehensive presentation of scientific methods of locating and determining stresses and calculating the required strength and dimensions of building material. By Edward R. Maurer. Chicago, American Technical Society, 1918. 126 pp., 2 pl., 7 tab., 8 × 5 in., cloth, \$1.

An elementary presentation of the subject, in which the use of higher mathematics has been avoided.

MEMBERSHIP

NEW MEMBERS

The following list comprises the names of those persons who became members during the period of May 10, 1918, to June 10, 1918.

- ABEEL, GEORGE H., JR., Cons. Min. Engr., 4111 Lafayette Ave., St. Louis, Mo.
 ALLEN, CARL A. Metal Min. Engr., U. S. Bureau of Mines, Butte, Mont.
 BECKER, P. FRANK Engr., Lightner Min. Co., 35 Nassau St., New York, N. Y.
 BOCK, JAMES H., Steam Shovel Foreman, Chino Copper Co., Santa Rita, N. M.
 CARRON, FRANK X., Civ. and Min. Engr. Rock Springs, Wyo.
 CROWE, THOMAS B., Mill Supt., Portland Mill, Portland Gold Min. Co., Victor, Colo.
 DOBSON, PERCY GREENSIDE, Min. Engr. and Geol., Crow's Nest Pass Coal Co.,
 Fernie, B. C., Canada.
 ESTABROOK, W. H., Capt., 3d Bat. 20th Engineers, A. E. F., Care Postmaster, N. Y.
 FRASER, O. B. J., Engr., International Nickel Co. of Canada, Ltd.,
 Port Colborne, Ont., Canada.
 GARRIDO, MANUEL F., Min. Engr. 109 W. Myrtle St., San Antonio, Tex.
 GRODSKY, VLADIMIR ALEXANDROVITCH, Cons. Engr., Motor Products Corp.,
 Detroit, Mich.
 HARRIS, FRANK B., Min. Engr., Phelps-Dodge Corp., Box 226, Tyrone, N. M.
 HARTMAN, ADOLPH E. Geol., Gypsy Oil Co., Tulsa, Okla.
 HERALD, FRANK A., Gen'l Mgr., Carl K. Dresser, 1208 Fayette National Bank
 Bldg., Lexington, Ky.
 HINDS, JOEL H. Geol., Carter Oil Co., Tulsa, Okla.
 LEGGE, FRED H., Constr. Engr., Q. M. Corps, U. S. Army, 214 A St., S. E.,
 Washington, D. C.
 LEWIS, CARL A., Min. Engr. 108 Warren Ave., Wollaston, Mass.
 LOBNER, CHARLES, Mgr., Croesus Gold Mines, Ltd., 42 Broadway, New York, N. Y.
 MCCRANEY, O. Gen'l Supt., White Caps Min. Co., Manhattan, Nev.
 MALOIT, FRANK, JR., Min. Engr. Kingston, N. M.
 MARQUAND, BRUCE Mill Supt., Sunnyside Min. & Mill Co., Eureka, Colo.
 MEREDITH, CARLTON Apartment 5-B-Beaconsfield, Houston, Tex.
 NEUMANN, L. MURRAY, Geol., The Carter Oil Co., Exchange National Bank Bldg.,
 Tulsa, Okla.
 OSLER, B. C. Chief Engr., J. S. Wentz Co., 532 Grant St., Hazleton, Pa.
 REIGART, JOHN R., Asst. Supt., Gwinn District, Cleveland Cliffs Iron Co.,
 Princeton, Mich.
 ROBERTS, J. K. Instructor and Geol., Emory and Henry College, Emory, Va.
 SCHLEIFER, K. A. Mgr., Ely Copperfield Associates, West Fairlee, Vt.
 STEWART, LLOYD L. Tyrone, N. M.
 TODD, CLARENCE T. Flotation Dept., Timber Butte Mill Co., Butte, Mont.
 WELDIN, WILLIAM ARCHIE, Blum, Weldin & Co., 83 St. Nicholas Bldg., Pittsburgh, Pa.
 WHITE, CLARENCE B., Pres., White & Bro. Inc., 412 North American Bldg.,
 Philadelphia, Pa.

Associates

- COLDHAM, J. C., Min. Engr., Gen'l Mgr., C. S. A. Mines, Ltd., Cobar, N. S. W.,
 Australia.
 FELTON, CORNELIUS C., Co. G, 35th U. S. Engineers, A. P. O. 735, A. E. F.

Junior Associates

- NESSIT, MILLARD F. U. S. Army.
 SCHRAEDER, WILLIAM D. Student, Lehigh University, So. Bethlehem, Pa.
 SENG, CHANG KEY, Asst. Engr., Hobart Iron Co., Care Elba Mine, Gilbert, Minn.

Change of Status, Junior Associate to Member

- GRAHAM, HERBERT W., Supt., Eliza Cupola Dept., Jones & Laughlin Steel Co.,
 Pittsburgh, Pa.
 MOSES, PERCIVAL SNEED 1st Lieut., National Army, A. E. F., France.
 SMITH, EVERETT W., Supt., Zinc Co., Ltd., Montauban, Conto Portneff,
 Quebec, Canada.

WENSLEY, ROGER L., Care William Young Westervelt, 17 Madison Ave.,
New York, N. Y.
YEN, CHUANG.....Instructed to hold everything.
Total Membership, June 10, 19186777

CANDIDATES FOR MEMBERSHIP

APPLICATION FOR MEMBERSHIP.—The Institute desires to extend its privileges to every person to whom it can be of service. On the other hand, it is not desirable that persons should be admitted to membership in classes for which they are not qualified. Members of the Institute can be of great service if they will make a practice of glancing through the list of applicants and promptly notifying the Committee on Membership, or the Secretary of the Institute, of any persons whom they think should not be classified in accordance with the list given.

Applications Lacking Endorsement

Applications for membership have been received from Mr. Hogg, Mr. Schuler, Mr. Teale and Mr. Wilkie, whose records are given below. These applications lack the necessary number of endorsers, but since these candidates live at some distance from the headquarters of the Institute, their records are published here in order that any members who are acquainted with them may be advised of the circumstances and may have an opportunity of writing to the Secretary endorsing these candidates.

Members

James Hogg, Euboea, Greece.

Proposed by P. D. Ahier.

Born 1871, Lanarkshire, Scotland. Hutchesontown Grammar School, Glasgow. Glasgow Technical College. Member, Institute of Min. and Met. and Federated Institute of Min. Engrs. 1890-95, Min. Apprentice, McCreaths & Stevenson, Glasgow. 1895-97, Underground Colliery Mgr., Podmore Hall Collieries, Staffordshire. 1897-1904, Mines Mgr., Aznalcollar Mines, Seville Sulphur & Copper Co., Seville, Spain. 1904-11, Mgr., Heredia Lead Mines, Linares, Spain. 1911-17, Mgr., Anglo-Greek Magnesite Co., Ltd.

Present position: Director and Mgr., Anglo-Greek Magnesite Co., Ltd.

Herman Schuler, Vallenar, Chile.

Proposed by Philip R. Gleason, John P. Chadwick.

Born 1878, Schaffhouse. 1898, Grad., Lyceum of Winterthur, Switzerland. 1902, Grad., Polytechnical School of Zurich, Switzerland, C. E. 1902-04, Civil engr., Swiss Govt. 1904-06, With Harkorft Co., steel construction, Duisburg, Germany. 1906-07, Hydraulic work in Silesia for German Govt. 1907-09, Min. Engr., Naltagua Copper Co., Chile. 1909-12, Railroad constructor for Chilian Govt.

Present position—1912 to date: Mine Operator, Vallenar Dist.

Donald Cook Wilkie, Serembau, Federated Malay States.

Proposed by

Born 1879, Dundee, Scotland. Brothers' school, Penang, Straits Settlements; Baptists' School, Rangoon, Burma; Donaldson's School, Dundee, Scotland; 1890-92, Wallacetown School, Dundee, Scotland. 1892-98, Mechanical and electrical construction and repair work; engr. experience; drafting room; shop at sea, Ross & Wilkie, Scotland. 1898-99, Asst. Engr., China Borneo Co., Ltd., Sandakan, B. N., Borneo. 1901-03, Salvage Dept., Tangong Pagar Dock Co., Ltd., Singapore. 1903-10, Engr., Pyritical Ore Installation, Sungei Besi recovery of tin stone from arsenical and sulphurous ores, The Straits Trading Co., Ltd., Sungei Besi, Malay States.

Present position—1910 to date: Supt. Engr., Linggi Plantations Ltd.

Associate

James Willie Teale, Euboea, Greece.

Proposed by P. D. Ahier.

Born 1882, Leeds, England. 1886-90, General education, Leeds School Board. 1890-95, Ossett School, near Wakefield. 1895-1902, Ossett Technical School, full

engr. course, science and art, South Kensington, obtaining Advanced Certificates. Correspondence courses. 1898-1903, Apprenticed to Bradley & Craven Ltd., Engrs., Iron & Brass Foundries, Wakefield, England. 1904-06, Asst. to mech. and elec. engr., Old Roundwood Collieries, Wakefield, England. 1907, Asst. to mech. and elec. engr., Hoyland Lilkstone Collieries, Ltd., Barnsley. 1908, Asst. to mech. and elec. engr., Bulcroft Main Collieries, Doncaster, England.

Present position: Mech. Engr., The Anglo-Greek Magnesite Co., Ltd.

The following persons have been proposed during the period May 10, 1918, to June 10, 1918, for election as members of the Institute. Their names are published for the information of Members and Associates, from whom the Committee on Membership earnestly invites confidential communications, favorable or unfavorable, concerning these candidates. A sufficient period (varying in the discretion of the Committee, according to the residence of the candidate) will be allowed for the reception of such communications, before any action upon these names by the Committee. After the lapse of this period, the Committee will recommend action by the Board of Directors, which has the power of final election.

Members

Herbert Addison, Denver, Colo.

Proposed by Richard A. Parker, Fred H. Bostwick, Carl Scholz.

Born 1877, Baltimore, Md. 1893, Grad., Polytechnic Institute, Baltimore, Md. 1893-98, Surveyor, Mine Foreman, etc., Greenwood Coal Co.; Laffin Coal Co.; Langcliffe Coal Co., Scranton, Pa.; Avoca Coal Co., Avoca, Pa., and Seneca Coal Min. Co., Pittston, Pa. 1898, Supt., Cummock Mines, Cummock, N. C. 1898-1910, Min. Engr. and Asst. Mgr., Union Coal & Coke Co., Denver, Colo.

Present position—1910 to date: Vice-Pres., Big Horn Collieries Co. and Big Horn Fuel Co.

Paul W. Avery, El Oro, Mexico.

Proposed by T. Skewes Saunders, E. L. Shera, Charles Hoyle.

Born 1880, Seward, Nebr. 1905, A. B.; 1906, A. M., Leland Stanford Jr. Univ. 1905-06, Asst. in Chemistry, Leland Stanford Jr. Univ. 1906-09, Asst. Chem.; 1909-10, Chem. and Assayer, Homestake Min. Co., Deadwood, S. D. 1910-11, Ch. Chem. and Assayer, Esperanza Min. Co., El Oro, Mex. 1911-12, Met. Engr., Asst. Mgr., La Leonesa Mines Ltd., Mutagalpa, Nicaragua. 1913-18, Met. Engr., Acting Mill Supt., Esperanza Min. Co.

Present position: Met., Esperanza Min. Co.; Mill Supt., Dos Estrellas Min. Co., Tlalpujahua, Mex., Met., Borda Antigua Co.

William Phillip Barba, Washington, D. C.

Proposed by Dr. H. M. Howe, G. Aertsen, Bradley Stoughton.

Born 1865, Philadelphia, Pa. Public Schools and High School, Philadelphia, Pa. 1880-1915, Chief Chem.; head of manufacturing of five depts.; General Mgr. of Sales; General Supt. and Mgr. of Sales; General Mgr.; Vice-Pres. and General Mgr.; Member of Board of Directors, Midvale Steel Co. 1915, Vice-Pres., Worth Brothers Co.; Vice-Pres., Wilmington Steel Co. 1916, Retired from Midvale Steel Co. and traveled. 1917, Major, Ordnance, R.C., United States Military Service.

Present position: Lt. Colonel, Ordnance, N. A.

Malcolm Bowden, Butte, Mont.

Proposed by Rush J. White, James F. Kemp, William C. Siderfin.

Born 1885, London, England. 1890-1901, Public Schools, Helena, Mont. 1903-08, Montana State School of Mines, Butte, Mont., E. M. 1901-02, Elkhorn Silver Min. Co. 1903, Amalgamator, Big Indian Min. Co., Helena, Mont. 1908-9, Sampler and Boss Trammer, Amalgamated Copper Co., Butte, Mont. 1910, Traveling in Europe. 1911-12, Engr., Elkhorn Silver Min. Co., Jefferson Co., Mont. 1912-14, Asst. Supt., Penobscot Min. Co., Hecla, Mont. 1915, Mill Foreman, York Gold Min. Co., York, Mont. 1917, Shift Boss, Elm Orlu Min. Co., Butte, Mont.

Present position: Asst. Foreman, Elm Orlu Min. Co.

Walter Stanley Brown, Cambridge, Mass.

Proposed by Carle R. Hayward, Charles E. Locke, Edward E. Bugbee.

Born 1881, Hyde Park, Mass. 1906, Massachusetts Institute of Technology, S. B. 1905, Federal Min. & Smelt. Co., Kellogg, Idaho. 1906, Constructing automatic weighing machine for belt conveyors, and member of firm, Wiard & Brown. 1907, Mine examination in Mexico, L. S. Noble; Engr. and Asst. to Mgr., El Tiro Copper Co., El Tiro, Ariz. 1908-10, Insurance engr., New England Bureau of United Inspection, Boston, Mass. 1910-18, Operating farm and engaged in surveying, Underhill Center, Vermont.

Present position: Research asst., Ore Dressing, Massachusetts Institute of Technology.

DeWitt Wheeler Buchanan, Chicago, Ill.

Proposed by C. M. Young, H. H. Stoek, Carl Scholz.

Born 1876, Chicago, Ill. 1898, Purdue Univ., B. S. 1898-99, Engineering Dept., Illinois Central R. R., 1899-1913, Pres., Wilmington Star Min. Co.

Present position—1913 to date: Pres., Old Ben Coal Corporation.

Denison K. Bullens, Philadelphia, Pa.

Proposed by Joseph W. Richards, Wm. H. Wiley, Robert H. Richards.

Born 1887, Newton, Mass. 1905-09, Massachusetts Institute of Technology, B. S. 1911, Post-Grad. Student, Graduate School of Applied Science, Harvard Univ. 1909-10, Instructor in Met., Sec'y of Faculty of School of Mines and Metallurgy, Pennsylvania State College. 1911, Met., Parish Mfg. Co., Reading, Pa. 1912, Met., Carbon Steel Co., Pittsburgh, Pa. 1913-16, Cons. Met., Philadelphia, Pa.

Present position—1916 to date: Met., Tindel Morris Co.

Charles Wesley Burgess, Joplin, Mo.

Proposed by John V. N. Dorr, O. Longacre, Jr., Charles T. Orr.

Born 1886, Garfield, Colo. 1905-09, Colorado School of Mines, Golden, Colo., E. M. 1914-18, Hamilton College of Law (Correspondence Course) LL. B. 1910, Asst. Supt., Oronogo Circle Min. Co., Oronogo, Mo. 1911, Supt., Clorone Min. Co., Webb City, Mo. 1912-13, Mgr., S. V. & D. Min. Co., Carthage, Mo. 1914-16, Supt., Baltic Min. Co., Webb City, Mo.

Present position—1917 to date: Special Representative, The Dorr Co.

Walter Edgar Cook, Camden, N. J.

Proposed by Allen Hoffer, D. T. Croxton, T. E. Pierce.

Born 1885, Pottstown, Pa. Public schools; private lessons and instruction in chemistry; course in chemistry, International Correspondence Schools. 1902-16, Asst. Chem., Blast Furnace Dept., Eastern Steel Co., Pottstown, Pa. 1916, Chem., Worth Bros. Plant, Midvale Steel & Ordnance Co., Coatesville, Pa.; Met. Dept., Simplex Automobile Co., New Brunswick, N. J.

Present position—1916 to date: Chem. and Met., Camden Forge Company.

Harry Edwin Crum, Lawrence, Kansas.

Proposed by Arthur C. Terrill, Erasmus Haworth, Geo. D. Morgan.

Born 1892, Mineral Point, Wis. 1896-1905, Common schools, Mineral Point, Wis. 1905-10, High School, Mineral Point, Wis. 1911-13, Lawrence College, Appleton, Wis. 1913-16, School of Engineering, Univ. of Kansas, Lawrence, Kansas. 1916, Geologist Aid, Empire Gas and Fuel Co., Bartlesville, Okla. 1916-17, Geol., Empire Gas and Fuel Co.

Present position: Geol., Central Oil Syndicate, Denver, Colo.

Keith Albert Cunningham, Guanajuato, Mexico.

Proposed by H. Vincent Wallace, Alvin B. Carpenter, A. B. W. Hodges.

Born 1877, London, England. 1888-1895, Queen Elizabeth's Grammar School, High Barnet, England; private study. 1895-1901, Ranching in Argentine Republic and Uruguay, S. A. 1901-02, Vacation to England and the Transvaal. 1902-03, Placer Mining, Barberton, Transvaal. 1903-04, Office, East Rand Proprietary Mines, East Rand, Transvaal. 1904-05, Prospecting, Cape Colony, South Africa. 1905-07, Mine Sec'y, Adamanda Gold Min. Co., Barberton, Transvaal. 1907-08, With J. H. L. Manisty, Stock Exchange, Johannesburg, Transvaal. 1908-09, In England and Mexico. 1909-15, Accountant; Mill and Plant Supt., Peregrina Min. & Mill. Co., Guanajuato, Mex.

Present position—1915 to date: Supt., Mexican Mill. & Transportation Co.

Marino Davila, Badajoz, Spain.

Proposed by Wm. Campbell, Bradley Stoughton, M. J. Scammell.

Born 1892, Badajoz, Spain. 1907, Instituto General y de Badajoz, B. A. 1916, Escuela Especial de Ingenieros de Minas, Madrid, E. M. 1916, Altos Hornos de Vizcaya, Bilbao, Spain. 1917, Bethlehem Steel Co., Sparrow's Point, Md.

Present position: Chile Exploration Co., New York City.

Frank Eichelberger, Helena, Mont.

Proposed by Alexander Leggat, J. J. Carrigan, D. A. Welch.

Born 1880, Urbana, Ohio. 1901-05, Literary course, Ohio State Univ., 1906-07, Michigan College of Mines. 1907-08, Partnership in custom laboratory. 1909, Supt., Niagara Mine, Cal. 1909-10, Mgr., Alexandra Min. Co., Cobalt, Ont., Canada. 1910, Cons. Engr., Cobalt Power Co. 1911-14, Supt. of Mines, for J. J. Edson, Jr. 1914, Supt., York Min. Co. 1915-16, Associated with J. J. Edson, Jr.

Present position—1917 to date: Vice-pres. and Engr., New York and Montana Testing & Engrg. Co.

Guy Hartwell Elmore, Philadelphia, Pa.

Proposed by Henry M. Chance, Daniel M. Barringer, Theron I. Crane.

Born 1861, Bergen, N. Y. 1883, Rensselaer Polytechnic Inst., C. E. 1884, Instructor, rational and technical mechanics, Rensselaer Polytechnic Inst., Troy, N. Y. 1885-90, With English Engine & Supply Co., Kansas City and Joplin, Mo. 1890-1900, Cooley and Elmore, Concentrating Plants, Joplin, Mo. 1900-15, Pres., American Concentrator Co., Joplin, Mo.

Present position: Cons. Engr., Coal and Ore Preparation.

Oliver Edwin Fox, Harlan, Ky.

Proposed by Walter R. Peck, Will Ward Duffield, Stephen E. Puckette.

Born 1866, Stony Point, Ky. 1883-86, Kentucky Univ., Lexington, Kentucky. 1886, Kansas City, Fort Scott & Gulf R. R. 1889, South Atlantic & Ohio R. R. 1889-98, Land and mine surveying; office work; and in mines, Central Coal & Iron Co., Central City, Ky. 1899-1912, Min. Engr. and Surveying Depts., Cambria Steel Co., Johnstown, Pa.

Present position—1912 to date: Member of firm, Fox, Peet & Fox, Harlan, Ky., and Big Stone Gap, Va.

Howard Ingram Frisbie, Anaconda, Mont.

Proposed by Frederick Laist, Louis V. Bender, James Kane Murphy.

Born 1885, Meridan, Kan. 1902, Grad., High School, Wartsburg, Wash. 1902-04, Washington State College, Pullman, Wash. 1905-06, Kansas State College, Manhattan, Kan. 1907-08, Armour Institute of Technology, Chicago, Ill. 1908-09, Motor Inspector, Illinois Steel Co., So. Chicago, Ill. 1909-10, Electrical Foreman, R. Williamson & Son, Chicago, Ill. 1910-12, Supt. of Construction, F. I. Howard, Los Angeles, Cal. 1912-14, Chief Electrician, Wyoming Coal Co. and Lyon Coal Co., Rock Springs, Wyo.

Present position—1914 to date: Cottrell Efficiency Engr., Washoe Reduction Works, Anaconda Copper Min. Co.

Joseph Furlong, Milwaukee, Wis.

Proposed by John V. N. Dorr, D. Cole, L. D. Ricketts.

Born 1874, Chicago, Ill. 1887, Grad., Grammar School. 1890-91, Commercial Course, night school. 1888-1918, Min. Machinery Dept., Manufacturing Dept., Cost and Accounting Dept., Allis-Chalmers Mfg. Co., Milwaukee, Wis.

Present position: Sales Engr., Allis-Chalmers Mfg. Co.

John Griffen, Scranton, Pa.

Proposed by Eli T. Conner, Charles Dorrance, R. S. Perry, J. V. N. Dorr.

Born 1888, Phoenixville, Pa. 1907-11, Lehigh Univ., C. E. 1911-12, Asst. Fuel Engr., Lehigh Coal & Navigation Co., Lansford, Pa. 1912-15, Asst. to President, Harrison Bros. & Co., Inc., Philadelphia, Pa.; Secretary, National Bauxite Co., and Boyd Smith Mines, Inc., Philadelphia, Pa. 1915-18, Fuel Engr., The Hudson Coal Co., Scranton, Pa.

Present position: Dist. Mgr., Anthracite Territory, The Dorr Co.

Edward Frank Kern, New York, N. Y.

Proposed by Robert M. Raymond, William Campbell, Louis D. Huntoon, Bradley Stoughton.

Born 1872, Knoxville, Tenn. 1897, Univ. of Tennessee, B. S. 1897-98, Special work in chem. and engrg., Univ. of Tennessee. 1898-1900, Post Graduate work in School of Chem., Univ. of Pennsylvania. 1900-01, Post Graduate work in chem. and met., Columbia Univ., Ph. D. 1901, Special work with Prof. Howe in met., Columbia Univ. 1902, Supt. of lead refinery, Canadian Smelt. Wks., Trail, B. C., Canada. 1903-05, Commercial research, Betts' Research Laboratory, Troy, N. Y.

Present position—1905 to date: Asst. Prof. of Met., Columbia Univ.

Bartholomew C. Leonard, South Fork, Pa.

Proposed by Andrew B. Crichton, M. J. Moore, D. M. Stackhouse.

Born 1877, Lacka Co., Pa. Attended Public and Night Schools. 1900-02, Webster Coal & Coke Co., Ehrenfeld, Pa. 1902-03, Eureka Co., Windber, Pa. 1903-04, South Fork Coal Min. Co., South Fork, Pa. 1904-07, Supt., South Fork Coal Min. Co. 1907-16, Asst. Cashier, First National Bank, South Fork, Pa.

Present position—1916 to date: Mgr. and Supt., Riverside Coal Min. Co.

James Ogier Lewis, Bartlesville, Okla.

Proposed by James H. Gardner, Alfred G. Heggem, W. A. Williams.

Born 1886, San Jose, Cal. 1917, Leland Stanford, Jr., Univ., Dept. of Geol., B. A. 1909-11, Geol., Associated Oil Co., Cal. 1911-12, Geol., Harry R. Johnson, Los Angeles, Cal. 1912-14, Geol., Robert B. Moran, San Francisco, Cal. 1914-15, Indian Service, Muskogee. 1915-18, Bureau of Mines, Petroleum Division.

Present position: Supt., Bartlesville Experiment Station, Bureau of Mines.

A. F. MacFarland, Chicago, Ill.

Proposed by Frank Garratt, Fred. Crabtree, R. J. Wysor.

Born 1890, Houston, Tex. 1909-13, Univ. of Michigan, Chem. Engr., B. S. 1913, Asst. Chem., Houston Cotton Oil Mill, Houston, Tex. 1914, Chem. Engr., Gager Lime & Mfg. Co., Chattanooga, Tenn. 1915-16, Chief Chem.; Steel Melter; John A. Crowley Co., Detroit, Mich.

Present position—1917 to date: Met., United States Ball Bearing Mfg. Co.

Edgar G. MacLay, Great Falls, Mont.

Proposed by Miles W. Krejci, John H. Klepinger, Russel B. Caples.

Born 1885, Benton, Mont. 1908, Harvard Univ., A. B. 1906-18, Asst. Chem.; Chem.; Chief Chem.; Anaconda Copper Min. Co., Great Falls, Mont.

Present position: Zinc Plant, Anaconda Copper Min. Co.

Frank Earl Nichols, Danao, Cebu, P. I.

Proposed by J. Clayton Nichols, A. H. Jones, J. E. Alley.

Born 1881, Minneapolis, Minn. 1895, Grad., San Diego High School, Cal. 1895-6, Printer, Hall & Kassler, El Cajon, Cal. 1899, New Era Business College, West Superior, Wis. 1917-18, Student, higher accountancy, La Salle Extension Univ., Chicago, Ill. 1899-06, Telegraph Operator, Great Northern C. St. P. M. & O. R. R., U. S. Signal Corps. 1907-09, Head Timekeeper, Tracks and Building Dept., Cebu Division, P. I. 1909-11, Concrete Inspector, Bureau Public Works, Cebu, Cebu. 1911-16, Supt., construction bridges, bldgs., docks and pile-driving works, Ainsworth & Power, Cebu, Manila.

Present position—1917 to date: Engr., Supt., Danao Coal Mines.

Hisao Sato, Funatsu, Gifuken, Japan.

Proposed by W. Watanabe, Tadashi Inouyé, B. Katsura.

Born 1884, Echigo, Japan. 1907, Grad., Imperial Univ., Tokio, Japan. 1907-18, Employed by Mitsui Min. Co.

Present position: Met. Engr., Mitsui Kamiaka Mine, Mitsui Min. Co.

Albert Silver, Shawmut, Cal.

Proposed by Ornan Bridges Smart, A. H. Jones, J. E. Alley.

Born 1889, Oakland, Cal. 1912, Univ. of California, Berkeley, Cal., B. S. 1908-09, Min., Keeler, Cal. 1911, Millman, Utah Copper Co., Garfield, Utah. 1911-12, Tool Nipper; 1912-16, Assayer, 1916-17, metallurgical laboratory, 1917-18, Mill Foreman, Tonopah Belmont Development Co.

Present position: Mill Supt., Belmont Shawmut Min. Co.

William Lawrence Uglov, Kingston, Ontario.

Proposed by J. M. Boutwell, C. V. Drew, W. H. Emmons.

Born 1884, Ottawa, Canada. 1905, B. A.; 1906, M. A., Queen's Univ., Kingston, Canada. 1911, School of Mining, Kingston, Canada, B. S. 1912, Univ. of Wisconsin, Geol., M. S. 1914, Geol., Univ. of Wisconsin, Ph. D. 1903, '09, '12 (Summers) Geological Survey of Canada, Ontario. 1906-07, Surveyor, Grand Trunk Pacific Ry. Surveys. 1910 (Summer), Ontario Bureau of Mines. 1911 (Summer), Prospecting in Ontario & Quebec with A. E. Barlow. 1913-14, Wisconsin Geological Survey on valuation of zinc and iron mines. 1914-15, Geol., Vinegar Hill Zinc Co., Platteville, Wis. 1915-16, Instructor in Geol., Univ. of Minnesota.

Present position—1916 to date: Min. Geol.

Andrew Walz, New York, N. Y.

Proposed by T. W. Mather, John W. Mercer, John V. N. Dorr.

Born 1882, New York, N. Y. 1902-05, Grad., Columbia School of Mines, E. M. 1905, Chem. Foreman, cyanide mill, Creston, Colorado Co., Sonora, Mex. 1906, Exploration and development work, Cobalt, Ont. 1907-09, Gen. Supt., Abangarez Goldfields of Costa Rica, Abangarez, Costa Rica. 1909-11, Asst. Engr. on examinations under A. H. Rogers, H. H. Knox, A. F. Kuehn. 1912-13, Min. Engr., Mines Management Co. 1914-16, Mgr., Winona Min. Co., Candor, N. C. 1916-17, Asst. to Pope Yeatman.

Present position—1917 to date: Min. Engr., Consulting Engr. Dept., Guggenheim Bros.

Louis William Williams, New York, N. Y.

Proposed by William H. Shearman, John V. N. Dorr, W. Horner Hendricks.

Born 1878, Brooklyn, N. Y. Scientific High School Course. Special course at Columbia, metallurgy and metallography. 1896-1900, General shop experience, R. Hoe & Co. 1900-18, practical mill experience and sales work, Union Dronn Steel Co.

Present position: Mgr., Union Dronn Steel Co.

Associates

Jules Albert Endweiss, Guanajuato, Mexico.

Proposed by Arthur Feust, Harry P. Smith, Joseph MacDonald.

Born 1882, New York, N. Y. Public School Education. 1894-8, Office boy; ticket clerk; stenographer, Mexican International R. R. 1898-9, Stenographer, Consolidated Kansas City Smelt. & Ref. Co., Mexico City, Mex. 1899-1900, Asst. Settlement Clerk, Ore Purchasing Dept., American Smelt. & Ref. Co., Aguascalientes, Mex. 1900-06, Cashier, Accountant, ore purchasing, etc., Dwight Furness Co., Guanajuato, Mex. 1906-14, Cashier; Auditor, Guanajuato Development Co.

Present position—1915 to date: Gen'l Mgr., Guanajuato Development Co. and allied interests.

Edward B. Jennings, Salt Lake City, Utah.

Proposed by J. C. Branner, J. C. Roberts, V. S. Rood, Ernest Gayford, Edward R. Zalinaki.

Born 1896, Florence, Wis. 1911-15, Salt Lake High School. 1915-16, Leland Stanford Jr. Univ., 1916, Colorado School of Mines. 1914 (Summer), Utah Apex Min. Co. 1915 (Summer), Asst. Engr., Utah Metal & Tunnel Co. 1916 (Summer), Asst. Engr., Utah Apex Min. Co.

Present position—1917 to date: Asst. Engr., Utah Apex Min. Co.

Curtis Franklin Martin, San Diego, Cal.

Proposed by Ellsworth H. Shriver, George W. Coffey, H. D. Kinney.

Born 1896, Kansas City, Mo. 1912, Grad., Public Schools, Kansas City, Mo. 1917, Started min. engr. course, International Correspondence School. 1912-18, Various occupations including several years at uncle's mines in Missouri.

Present position: Private, Co. B, 27th Engrs., Camp Meade, Md.

Junior Associates

Harry Joseph Deutsch, Rapid City, S. D.

Proposed by Charles Bentley, C. C. O'Hara, W. C. Bochert.

Born 1894, Rapid City, S. D. 1913, Grad., High School, Rapid City, S. D. Three years in South Dakota School of Mines. 1916, Assayer, Mine Surveyor, New Reliance Gold Min. Co., Trojan, S. D. 1917, Assayer and Millman, Trojan Min. Co., Trojan, S. D.

Present position: Senior, South Dakota School of Mines.

Downs McCloskey, Durango, Colo.

Proposed by W. F. Dietrich, C. F. Tolman, Jr., Welton J. Crook.

Born 1895, Durango, Colo. 1901-09, Grade School, Park School, Durango, Colo. 1909-14, Grad., Durango High School. 1914 (Summer), Trammer, Mucker, etc., Copper Hill Mine, La Plata City, Colo. 1916 (Summer), Assay helper, Robin Assay Office, Durango, Colo. 1917 (Summer), Topography and Geol., Stanford Univ.

Present position—1914 to date: Student, Stanford Univ., Cal.

Elmer Walter Pehrson, Stanford Univ., Cal.

Proposed by W. F. Dietrich, C. F. Tolman, Jr., Welton J. Crook.

Born 1896, San Jose, Cal. 1902-10, Grammar School, Normal Training School, San Jose, Cal. 1910-14, San Jose High School. 1916 (Summer), Sampler, Calaveras Copper Co., Copperopolis, Cal. 1917 (Summer), Concentrate Man, Empire Cyanide, Grass Valley, Cal. 1918, Teaching Asst. in Assaying, Stanford Univ., Cal.

Present position—1914 to date: Student, Stanford Univ.

William Ernest Petritz, Butte, Mont.

Proposed by C. H. Clapp, Theodore Simons, C. H. Bowman.

Born 1890, Anaconda, Mont. 1907-09, Univ. of Michigan. 1909-10, Brown's Business College, Rockford, Ill. 1910-13, Bookkeeper, Rockford Brewing Co., Rockford, Ill. 1913-14, Miner, Renton Coal Mines, Wash. 1914-17 (Vacations and odd intervals), Miner, Anaconda Copper Min. Co. 1917-18, Tram Boss, West Cohesa mine, Anaconda Copper Min. Co.

Present position—1914 to date: Student, Montana State School of Mines.

*Change of Status—Junior Associate to Member***Bert F. Smith, Spokane, Wash.**

Proposed by Frederick Burbidge, Preston Locke, L. K. Armstrong.

Born 1889, Liverpool, England. 1915, Grad., School of Mines, Univ. of Idaho. 1907-14 (Summers), General mining work, Central Idaho. 1915, Engr., El Tigre mine, Mexico. 1916, Sampler, Mace mine, Mace, Idaho; Engr., Federal Min. & Smelt. Co., Wallace, Idaho.

Present position—1916 to date: Asst. Engr., Examination of Mines, American Smelt. & Refg. Co.

Stanley Hughson Zimmerman, American Expeditionary Forces, France.

Proposed by J. M. Boutwell, C. V. Drew, F. W. McNair.

Born 1889, Milan, Mich. 1906, Public School, Milan, Mich. 1908-10, High School, Ann Arbor, Mich. 1911-12, Michigan College of Mines. 1915, Grad., Michigan College of Mines, E. M. & B. S. 1906-08, Lumbering, Idaho, Washington and B. C. 1909, Mucker, Ojibway Min. Co. 1912, Timberman, machineman, shaftman, Veteran mine, Nevada Cons. Copper Co., Veteran, Nev. 1913, Draftsman, Nevada Cons. Copper Co., Ruth, Nev., and Miner, Goldfield Cons. Min. Co. 1914, Designer, draftsman, Diamond Crystal Salt Co., St. Clair, Mich. 1915-17, Min. Captain, San Francisco mine, Morococha Min. Co., Morococha, Peru, S. A.

Present position—American Expeditionary Forces.

CHANGE OF ADDRESS OF MEMBERS

The following changes of address of members have been received at the Secretary's office during the period May 10, 1918 to June 10, 1918.

This list together with the list published in Bulletins Nos. 133 to 138, January to June, 1918, and the foregoing list of new members, therefore, supplements the annual list of members corrected to Jan. 1, 1918 and brings it up to the date of June 10, 1918.

ADAMS, ARTHUR K. High Street, Spencer, Mass.
 ABBE, FREDERICK R., Capt., Co. B, 33d Engineers, A. E. F., Care Postmaster, N. Y.
 AMBLER, HARRY A., 1st Lieut., O. R. C., 30th Infantry, A. E. F., Care Postmaster,
 New York, N. Y.

ANDERSON, L. DOUGLASS, Mgr. of Smelters, Intermountain District,
 U. S. Smelt. Refin. & Min. Co., Salt Lake City, Utah.

ARCHBALD, HUGH ... Capt., 311th Infantry, N. A., A. E. F., Care Postmaster, N. Y.
 BAENEY, LUTHER W. 23 Randolph Ave., Waterbury, Conn.

BAKER, RAYMOND FRANK, Private, Intelligence Section, Headquarters 90th Div.,
 Camp Travis, Texas.

BANKS, H. R. 2d Lieut., Canadian Engineers, C. E. F.
 BARKER, HENRY A., Gen'l Mgr., Sociedad Esplotadora de Caylloma Consolidado,
 Casilla 180, Arequipa, Peru, S. A.

- BARTON, L. A., Capt., 604th Engineers, Vancouver Barracks, Vancouver, Wash.
 BATTEN, H. L., Lieut., Canadian Engineers, C. E. F., Care Bank of Montreal,
 London, England.
 BAUSE, JOHN R., Co. M, First Army Headquarters Regiment, A. E. F.,
 Care Postmaster, N. Y.
 BAYLESS, JOHN Z. 3710 E. John St., Seattle, Wash.
 BENSEL, J. A. Major, U. S. R., Norfolk, Va.
 BETTERTON, JESSE O. 3201 Hamilton St., Omaha, Neb.
 BIRKETT, HOWARD, Lieut., Aviation Section, U. S. Signal Corps, Ellington Field,
 Houston, Tex.
 BLAIR, GEORGE S., 1st Lieut., 320th Field Artillery, A. E. F., Care Postmaster, N. Y.
 BOOTH, L. E. Watertown Arsenal, Det. E. O. C., N. A., Watertown, Mass.
 BOUDWIN, WALKER J., Corp., Co. C, 25th Engineers, A. E. F., Care Postmaster, N. Y.
 BOWMAN, REGINALD G., 1st Lieut., Engrs. U. S. R., Int., Ord. Dept. No. 4, A. E. F.,
 Care Postmaster, N. Y.
 BRADLEY, CLARENCE I., Convois Automobile Section, 585, S. S. U., Par., B. C. M.,
 France.
 BRASSERT, H. A. Peoples Gas Bldg., Chicago, Ill.
 BRIBER, F. E. Co. D, 314th Engineers, 89th Div., Camp Funston, Kansas.
 BRINKER, ARTHUR C., The Buena Tierra Min. Co., Ltd., Santa Eulalia, Chihuahua,
 Mexico.
 BRONSON, EDMOND B. Suite 926, 111 Broadway, New York, N. Y.
 BROOKS, FLOYD R., Lieut., Engineers Training Depot, St. Johns, P. Q., Canada.
 BROOKS, JOHN M. JR. 749 N. Fifth Ave., Knoxville, Tenn.
 BROWN, CLYDE L. Box 1308, Tonopah, Nev.
 BROWN, T. E. 35 Nassau St., New York, N. Y.
 BROWN, W. SINCLAIR, Dept., Aeronautical Supplies, Air Board Offices, Swansea, Eng.
 BUCK, LEONARD J., Naval Ensign, Naval Aviation Training School, Cambridge, Mass.
 BURG, ROBERT S., 2d Lieut., 5th Reg., 15th Bat., F. A. R. D., Camp Jackson, S. C.
 BURNS, J. J. Co. 1B, E. R. O. T. C., Camp Lee, Va.
 CALDER, NORMAN L., Lance Corp., W. R., No. 319499, Admiralty Works, I. W. & D.
 Royal Engineers, Southwick P. O., Sussex, England.
 CANTON, WILLIAM R., Battery A, 62d Regiment, C. A. C., Presidio,
 San Francisco, Cal.
 CARLYLE, WILLIAM A. Citizen Bldg., Sparks St., Ottawa, Canada.
 CARROLL, WALTER. 108 Ordnance Depot Co., Camp Sherman, O.
 CHAPMAN, IRVING A., Ensign, U. S. Navy, U. S. Submarine Base, New London, Conn.
 CHASE, MARCH F. Grapevine Road, East Gloucester, Mass.
 CLAYTON, CHARLES Y. Room 4, Bureau of Mines, Pittsburgh, Pa.
 CLEVINGER, G. H. 314 Mining Exchange Bldg., Colorado Springs, Colo.
 COHEN, MAXWELL B., Meteorological Section, A. & M. College, College Station, Tex.
 CONRADE, R. A. 305 Newhouse Bldg., Salt Lake City, Utah.
 CONSTINE, JOHN. Care Ray Consolidated Copper Co., Ray, Ariz.
 COPELAND, N. R. Lieut., Camp Dick, Dallas, Tex.
 CORSA, DEAN, Capt., Co. D, 512th Engineers, A. E. F., Care Postmaster, N. Y.
 CROSS, WILBUR L., JR. 1660 Wyoming Ave., Scranton, Pa.
 CURTIS, FRED S., Capt., Engrs. R. C., 17th Engineers, U. S. P. O., No. 701, A. E. F.,
 France.
 DAKE, WALTER M., JR. 624-626 Metropolitan Bldg., Denver, Colo.
 DAVIES, R. G. 317 Hobart Bldg., San Francisco, Cal.
 DAVIS, THORNTON, 1st Lieut., 13th Field Artillery, A. E. F., Care Postmaster, N. Y.
 DEL MAR, ALGERNON. Nelson, Nev.
 DODGE, CLEVELAND E., Lieut., 304th Field Artillery, A. E. F., Care Postmaster, N. Y.
 DOWD, JAMES J. 6th Co., C. B., Fort Monroe, Va.
 DOWNES, FRANK A. 2d Lieut., 535th Engineers, Camp Lee, Va.
 DRUM, FRANK G., 910 American National Bank Bldg., 485 California St.,
 San Francisco, Cal.
 EDWARDS, JOHN R. Brown University, Providence, R. I.
 ELDRIDGE, ROBERT B. Ward, Colo.
 ERIC, A., U. S. Government Explosives Plants, 16 East 42d St., New York, N. Y.
 EUSTIS, FREDRIC A., Special Agent, Shipping Board, Perry-Payne Bldg., Cleveland, O.
 EYOUT, DJEAD. Asst. Geol. Engr., Phelps-Dodge Corp., Tyrone, N. M.
 FARRAND, I. W. Sgt., Co. A, 27th Engineers, A. E. F., care Postmaster, N. Y.
 FINK, WILLIAM N., care Cusi-Mexicana Mining Co., Apartado 125, Chihuahua,
 Mexico.
 FINKELDEY, WILLIAM H. 101 South 2d St., Lehigh, Pa.
 FOESTER, HALLARD W. Officers' Training School, Camp Lewis, Wash.

- FORBES, DAVID L. H., Teck-Hughes Gold Mines Ltd., Kirkland Lake, Ont., Canada.
 FOWLES, CHARLES.....Care El Paso Foundry & Machine Co., El Paso, Texas.
 GARRISON, MURRAY E., Flying Cadet, Squadron A53, Aviation Barracks,
 Berkeley, Cal.
 GILL, JAMES P.....Montgomery City, Mo.
 GILL, PHILIP L.....Room 44, 40 Cedar St., New York, N. Y.
 GILLETTE, G. MARSHALL, Mgr., Maryland Div., The Consolidated Coal Co.,
 Frostburg, Md.
 GILLIS, JULIUS H., Chief Draftsman, British America Nickel Corp., Ltd.,
 Sudbury, Ont., Canada.
 GIROT, PIERRE.....Capt., 22d Regiment, Field Artillery, French Army.
 GORE-LANGTON, C., U. S. Engineers, Special Service, A. E. F., Care Postmaster, N. Y.
 GREENAN, J. O.....Headquarters Co., 27th Engineers, Camp Meade, Md.
 HALLORAN, WILL, Battery A, 146th Field Artillery, 41st Div., A. E. F.,
 Care Postmaster, N. Y.
 HANST, JOHN FABER.....Instructed to hold everything.
 HARMS, PURL L., Capt., 29th Co., 3d Infantry Replacement Regiment,
 Camp Gordon, Ga.
 HAYES, FRANCIS H., Major, Headquarters, 79th Brigade, 40th Division,
 Camp Kearny, Cal.
 HEAD, J. L., 2d Lieut., Co. C, 513th Engineers, A. E. F., Care Postmaster, N. Y.
 HEROLD, STANLEY CARROLLTON.....Care Gypsy Oil Co., Tulsa, Okla.
 HERR, LAURISTON B., JR., 1st Lieut., Headquarters Anti-aircraft Service, A. P. O. 728,
 A. E. F., France.
 HOOD, J. PARKE, 2d Lieut., Engrs. R. C., Co. D, 312th Engineers, Camp Pike, Ark.
 HORCASITAS, A. S., Min. Engr., South American Development Co., Apartado 655,
 Guayaquil, Ecuador.
 HUBBARD, WILLIAM H., JR., Engr., Northport Smelt. & Refin. Co.,
 Northport, Washington.
 HUBER, J. EARL, Co. B, 14th Machine Gun Bat., A. E. F., Care Postmaster, N. Y.
 HURD, RUKARD.....Major, E. R. C., State Capitol, St. Paul, Minn.
 HYATT, CHARLES S., Chem., Co. D, 30th Engineers, A. E. F., Care Postmaster, N. Y.
 JARVIS, ROYAL P., Care Cia. Metalurgica de Torreon, Apartado Postal No. 93,
 Torreon, Coah., Mexico.
 JEWETT, FRANK G.....1142 McKnight Bldg., Minneapolis, Minn.
 KAMIMURA, ICHIRO, Metal Min. Dept., Care Mitsubishi Min. Co.,
 Maru-no-uchi, Tokyo, Japan.
 KANO, SHINICHI, Chief Engr., Tanaka Min. Co., Ltd., 102 Kita-ura-machi,
 Naito-Shinjuku, Tokyo, Japan.
 KENNEDY, A. T., Capt., U. S. R. Engineers, Care General Purchasing Office, P. O. 702,
 A. E. F., France.
 KENNEDY, FRANK A.....Care Butler Bros., Pongilly, Minn.
 KINNEY, S. P., 2d Lieut., Chemical Service Section, American University,
 Washington, D. C.
 KOROTKIN, WILLIAM, Engr. Dept., Burro Mountain Branch, Phelps-Dodge Corp.,
 Box 39, Tyrone, New Mexico.
 KROGH, ALVIN T., Sgt., Chemical Service Section, N. A., Bureau of Mines Experiment
 Station, American University, Washington, D. C.
 LANDERS, WILL. H., Capt., Engrs. U. S. R., Engineer Officer, Camp No. 20,
 A. P. O. No. 705, A. E. F., France.
 LEE, ARTHUR L.....Engr., Electric Point Min. Co., Leadpoint, Wash.
 LEONARD, H. R., Supt., Projectile Finishing Dept., Harrisburg Pipe & Pipe Bending
 Co., Harrisburg, Pa.
 LEWIS, J. WHITNEY, 2d Lieut., U. S. R., Care United States Geological Survey,
 Springfield, Ga.
 LIDVALL, EDWARD ROBERT, Co. A, 27th Engineers, A. E. F., Care Postmaster, N. Y.
 LIHME, C. BAI.....Watch Hill, Rhode Island.
 LINDLEY, J. GARY, Gas Defence Service, Care Goodyear Bldg.,
 Long Island City, N. Y.
 LINDSLEY, HALSTEAD...Major, Ordnance Dept., A. E. F., Care Postmaster, N. Y.
 LINDSLEY, THAYER, Capt., Heavy Artillery Training Camp, A. E. F.,
 A. P. O. No. 123, France.
 LINTNER, EDWIN J.....520 So. 2d Street, Ironton, Ohio.
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The deaths of the following members were reported to the Secretary's office during May 10, 1918, to June 10, 1918.

Date of Election.	Name.	Date of Death.
1888	Brown, Amos P.....	Oct., 1917.
1904	Clark, Edward W.....	
1889	Fearn, Percy LeR.....	Apr. 16, 1918.
1914	Gorman, T. C., Killed in Action.....	Mar. 18, 1918.
1914	Perry, Edward H., Killed in Action.....	Mar. 30, 1918.

BIOGRAPHICAL NOTICE

DR. ARTHUR H. ELLIOTT

Dr. Arthur H. Elliott has been connected with the gas industry for upward of thirty-eight years and was a chemist to whom the industry is deeply indebted for the application of the science of chemistry to its problems and processes. He was born in London, England, in 1851, and was the son of a physician. While a child he was taken to France, where he received his early education, learning to speak the French language before his native English. His father having destined him for the medical profession, he commenced his studies on his return to England, but his attention being attracted to chemistry, he gave up the study of medicine to pursue that of chemistry. While still a student, he obtained a reputation as an iron and steel analyst, publishing two methods of analysis, one for the determination of sulphur and the other for the determination of carbon in cast iron.

On his graduation from the School of Mines at South Kensington, he left England intending to go to Australia, where an uncle resided, having in mind also the possibility of a trip to China. On his arrival in New York, he met Professor Charles F. Chandler, to whom he had a letter of introduction, and who induced young Elliott to remain. He graduated from Columbia College with the degree of Doctor of Philosophy in 1883. He became demonstrator in chemistry at the College of Pharmacy and afterward professor of chemistry and physics at the same college.

He became connected with the Municipal Gas Lighting Co. in May, 1880. In November, 1884, when consolidation took place, he became engineer-chemist of the Consolidated Gas Co., which position he held until May, 1910, when he resigned, but was retained as consulting chemist until his death. Recently Columbia University conferred on him the honorary degree of Master of Science.

He was a member of the Society of Gas Lighting, American Gas Institute, Illuminating Engineering Society, Society of Chemical Industry, American Chemical Society, and other societies and institutions. He became a member of this Institute in 1895. He was esteemed by all who had the privilege of his friendship, in fact to know him was to love him. He left the impress of his personality on the societies to which he belonged and on all who came in contact with him. He always was ready to lend a helping hand, and many young members of the chemical and engineering professions are deeply in his debt for assistance which he gave them in their careers.

He was married in 1887 to Miss Kate P. Uglow, and is survived by his wife, three daughters and one grand-daughter.

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DISCUSSION OF THIS PAPER IS INVITED. It should preferably be presented in person at the Colorado Meeting, September, 1918, when an abstract of the paper will be read. If this is impossible, then discussion in writing may be sent to the Editor, American Institute of Mining Engineers, 29 West 39th Street, New York, N. Y., for presentation by the Secretary or other representative of its author. Unless special arrangement is made, the discussion of this paper will close Oct. 1, 1918. Any discussion offered thereafter should preferably be in the form of a new paper.

Possible Existence of Deep-seated Oil Deposits on the Gulf Coast

BY ANTHONY F. LUCAS, WASHINGTON, D. C.

(Colorado Meeting, September, 1918)

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INTRODUCTION

THE discovery of oil in 1901 on the Spindletop dome, Texas, inaugurated a new industry on the Gulf Coast, an industry which has grown with the discovery of successive fields, until today it engages the services of thousands of workers and employs enormous capital. New fields are being discovered from time to time and doubtless some still remain to be found, though of late years discoveries have become more infrequent. Nowadays several hundred dry holes are drilled each year in a fruitless and blind effort to discover new fields, for as yet geologic science has developed no effectual method of locating the coastal oil deposits in advance of drilling.

Moreover, despite the occasional discovery of new fields, the total production of the Gulf Coast is today no greater than it was in 1906, for the added production of the new fields has been offset by the rapid decline and more or less complete exhaustion of some of the older ones. Careful geologic work within the fields has in some cases increased the production temporarily, but has developed no really new supplies. The Gulf Coast oil industry seems to have passed its period of greatest expansion and to be declining at a fairly steady rate, and this condition is naturally viewed with alarm by the more farsighted operators.

In my opinion, the time has come for the adoption of radical and aggressive methods of prospecting, and a fraction of the money wasted yearly in drilling shallow wells in hopeless locations might well be devoted to this purpose. Many facts lead me to believe that all the salt-dome oil has had a common origin; that it has migrated up from considerable

depth along lines of structural weakness; and that a deep well, properly located, stands an excellent chance of discovering the parent reservoir and thus of developing new and probably great supplies. This paper is presented as a discussion—necessarily hypothetical and based largely on personal opinion—of the possibility of encountering deep-seated oil deposits beneath the salt domes.

SALT-DOME STRUCTURE

All of the oil produced in the coastal region of Texas and Louisiana is probably associated with salt domes, though in Goose Creek, Edgerly, and one or two other fields no salt has yet been actually penetrated. As a result of the innumerable wells that have been drilled on the various domes, it is now known that a typical salt dome consists of a very thick mass of pretty pure rock salt, generally almost flat-topped, but sloping abruptly away from the rim on every side. The flat top of the salt is generally covered by rock 25 to several hundred feet thick, and consisting chiefly of limestone, dolomite, anhydrite, or gypsum, with generally more or less sulphur. The sediments above the salt are slightly domed and those on the sides of the salt mass generally slope at angles of 30° to 60°, and in some fields at even greater angles. These sediments consist of sand, gravel, shale, and gumbo, arranged in beds so lenticular and irregular that they can seldom be correlated from one well to another.

Of the many salt domes already discovered on the Coastal Plain, there are no two whose structures are identical. Each has its individual peculiarities of size, height, steepness, character of cap rock, and wealth or absence of oil. Some of the domes, like the phenomenally rich Spindletop, are only a few hundred acres in extent; others, like Humble, Damon Mound, and some of the salt islands of Louisiana, cover several square miles. Most of these domes are roughly circular in outline, but some, like South Dayton and Blue Ridge, are greatly elongated. Many of the domes form more or less distinct mounds at the surface, the highest rising 100 ft. or so above the surrounding plain, but others are overlain by sunken areas or lakes, and still others by perfectly level country in which no clue to the structure can be obtained. The cap rock of some mounds, like Sulphur and Bryan Heights, contains commercial quantities of sulphur, whereas that of others contains only traces. Gypsum and anhydrite are almost the sole constituents of some cap rocks, whereas in others limestone and dolomite greatly predominate. Pyrite is common in nearly all, and in one or two, galena, sphalerite, chalcopyrite, etc., have been found in small quantities.

Finally, the salt itself is physically different in different mounds; in most of them it is hard and well crystallized, but in others it is soft, granular, and almost incoherent. As may be seen in the salt mines at

Petite Anse and Grand Cote Islands, La., the salt is characterized by peculiar gray streaks or markings. These do not seem to have any regular trend, and are often contorted and twisted into the most fantastic shapes (see Fig. 1).



FIG. 1.—GRAY MARKINGS ON SALT, AS FOUND AT PETITE ANSE AND GRAND COTE ISLANDS.

OCCURRENCE OF OIL ON THE SALT DOMES

The salt-dome oil occurs under conditions just as irregular and impossible to determine in advance of drilling as the structure of the dome itself. The oil at Spindletop occurs chiefly in a hard cavernous limestone layer which forms the cap rock of the dome. At Welsh, Saratoga, and many other fields, the oil is found in the loose sands above the cap rock. At Anse la Butte, Damon Mound, and some other fields, it occurs partly or wholly in the deeper and sharply dipping sands which lie on the flanks of the domes and below the level of the cap, while in the Humble field it is found under all three conditions. In only one dome, Belle Isle, La., has oil been found within the salt itself, and in this locality the salt contains much gas under enormous pressure and also a small quantity of high-grade paraffin oil.

As few of the domes are more than a mile across, it is evident that the productive area is very limited in extent, though where oil occurs on the flanks of the salt mass the field is somewhat larger. The largest

field, Humble, is, however, less than 2 miles square. Salt-dome oil thus occurs under conditions very different from those in the Appalachian fields, where the oil is found in well defined gently folded sands traceable over large areas. In the Gulf Coast fields the wells are more expensive and less likely to find oil, and though their production may be enormous for a short period their decline is usually rapid.

Of the four or five dozen salt domes now known in Texas and Louisiana, less than two dozen have produced oil in commercial quantities and less than one dozen have become really important fields. Many are perfect blanks as far as production is concerned, and though apparently similar to richly productive domes and characterized by apparently identical surface indications, they may yield only a puff of gas while drilling and a showing of oil so slight that it may have found its way into the well from the surface machinery. These conditions suffice to emphasize the practical importance of arriving at a solution of the origin of the domes and their associated minerals, and of determining, if possible, the ultimate source of the oil and the conditions which have controlled its migration and accumulation.

PRESENT METHODS OF EXPLORATION AND DEVELOPMENT

The search for oil on the Gulf Coast at present consists of two phases, the search for new and hidden salt domes, and the drilling of old and plainly visible domes which have yet produced no oil. As the occurrence of oil on the dome is very irregular, two dozen or more wells may be drilled before commercial supplies are found. As already stated, these supplies may be phenomenally rich considering the area involved, but they soon become exhausted and the search must then be resumed.

Owing to the flat and monotonous topography of the Coastal Plain and to the fact that the oil-bearing rocks are overlain by a thick and structureless mantle of Pleistocene deposits, ordinary methods of geologic field work are of no avail. Some domes are marked by prominent and unmistakable hills, but others appear only as low and inconspicuous mounds. The so-called gas mounds, and even large ant hills, have sometimes been confused with true domes, and wells have been drilled on them. Other domes have no topographic reflection whatsoever and the search for such domes therefore resolves itself into a search for surface indications of oil; gas seeps, the so-called paraffin-dirt, oil or asphalt exudations, sulphur or salt springs, and mud volcanoes are commonly regarded as the best indications. Even if they lead to the discovery of a new salt dome, however, there is, of course, no assurance that the dome will prove productive of oil.

Quite recently several different and as yet untried methods for locating

salt domes have been proposed. Shaw's suggestion,¹ that the difference in specific gravity between the ordinary sediments and the salt, limestone, etc., composing the dome may be large enough to cause perceptible gravity anomalies, appears plausible and has received much favorable mention. Rogers' work² on California oil-field waters has shown that the water associated with the oil is very different chemically from the ordinary ground water of the region, and it may be that the analysis of water from shallow wells on the Gulf Coast will prove an aid in the discovery of salt domes.

Another method for locating hidden domes has been suggested by a high authority in geologic and physical science, whose name I am not as yet permitted to mention. This method is based on the fact that the domes are composed chiefly of salt, gypsum, and limestone, while the surrounding material is clay, silt, and gravel. Such difference in rock character is likely to be marked by at least a small deflection in the magnetic currents, and if this deflection exists, the presence of a dome might be detected by a sufficiently delicate instrument. The scientist I refer to has perfected an extremely delicate dipping needle, which, it is claimed, will easily detect magnetic differences only one-twentieth as strong as the ordinary dipping needle can detect. Knowing the capabilities of the gentleman, I am sure that as soon as he is ready to release his discovery he will receive every consideration, not only by leading scientists but also at the hands of the oil companies who are so vitally interested in the discovery of new domes.

WIDE DISTRIBUTION OF OIL IN THE MEXICAN GULF REGION

Before discussing the source and origin of the salt-dome oil, a brief review of the known occurrences of oil in regions adjacent to the Gulf of Mexico, and especially under the Gulf, may be of interest. Showings of oil are found in many localities along the littoral of the Gulf of Mexico and the Caribbean Sea, including points in Venezuela, Colombia, Panama, Costa Rica, Honduras, Salvador, Guatemala, the Isthmus of Tehuantepec and the Tampico region of Mexico, and the coast of Texas and Louisiana. Indications of oil are also found in Cuba, the Isle of Pines, Panama, Haiti, and Santo Domingo, the Lesser Antilles, the Windward and Leeward Islands, and Trinidad.

In the Isthmus of Tehuantepec, oil in considerable quantity is produced from salt domes apparently similar to those in Texas and Louisiana. In the tremendously rich Tampico region, the oil is associated with ig-

¹ E. W. Shaw: Possibility of Using Gravity Anomalies in the Search for Salt-dome Oil and Gas Pools. *Science*, New ser. (Dec. 7, 1917), 46, No. 1197, 553-556.

² G. S. Rogers: Chemical Relations of the Oil-field Waters in San Joaquin Valley, California. *U. S. Geological Survey, Bulletin* 653 (1917).



FIELDS OF FLOATING OIL IN THE GULF OF MEXICO

(From Lieut. Soley's article, Scientific American Supplement, Apr. 9, 1910.)

FIG. 2.

neous plugs and dikes, and in Cuba and the Isle of Pines, it occurs either in serpentine (or decomposed igneous rock) or near the contact between serpentine and highly folded sedimentary rocks. Evidences of igneous action are plentiful throughout the Mexican Gulf region except in that portion belonging to the United States.

Perhaps the most interesting indications of oil in the whole region are those which reveal its presence beneath the Gulf of Mexico itself. Lieut. John C. Soley, U. S. N.,³ in his paper on "The oil fields of the Gulf of Mexico," gives a chart showing the location of all reported occurrences, and discusses their origin and geologic significance. This chart is reproduced herewith (Fig. 2), together with extracts from this interesting paper.

Location.—The accompanying chart shows the position and extent of the oil field as located by the reports received during the last five years.⁴ The area within which floating oil has been found extends from latitude 26 deg. N. to 28 deg. 30 min. N., and from longitude 89 deg. W. to 93 deg. W. As the location extends in the direction of the flow of the main current of the Gulf Stream, it is probable that the area shown is much larger than the actual area from which the oil escapes. The most active part of the field is about 120 miles south of Trinity Shoal off the Louisiana coast.

History.—The appearance of bitumens in various shapes in the Gulf of Mexico dates back to the earliest history of this country. . . . The floating oil has been noticed from time to time and has been reported in the newspapers occasionally, but in later years records have been kept carefully so that it is possible to locate the origin of the field and to determine its extent. . . .

Near the shore at Sabine Pass, west of the west jetty, there is a deposit of a viscid tarry liquid of bituminous odor, which impregnates the mud, and when the mud is stirred by wave action or mechanically, the globules of oil rise to the surface and spread out so that, in storms, there is no break, and the location has become celebrated as an oil pond. The appearance is irregular and the origin is uncertain; the oil probably occurs in a porous bed under the water, whose cover is sufficiently pervious to permit a constant though very slow seepage, sufficient to allow the overlying mud to become saturated.

A peculiar substance called sea wax is frequently found on the beaches between Sabine Pass and Matagorda. This is found in large cakes as large as 6 or 8 ft. long and 1 or 2 in. thick. It is undoubtedly a petroleum or asphaltum residuum and its presence points to the existence of springs of liquid bitumen somewhere in the Gulf.

The chart shows a number of oil spots south of Trinity Shoal from Ship Shoal to Sabine Bank, but these have only been reported in later years and are undoubtedly the refuse from the oil ships and barges when they clean tanks before going into Sabine Pass.

Along the Mexican coast and near Campeche Bank, floating oil is reported occasionally, but the first record appears in 1907, and it may come from either of two sources; from the northern field drifting before a gale or the overflow from the Mexican oil fields.

During the last 7 years, the reports from vessels that have passed through the oil field in the Gulf have been frequent, principally because attention has been especially directed to it; the positions where it has been reported are plotted on the chart,

³ *Scientific American Supplement* (Apr. 9, 1910), 69, 229.

⁴ Note that Lieut. Soley's paper was published in 1910.

so that its limits have been determined with considerable accuracy, and the point of origin has been located almost exactly as being at latitude 27 deg. 30 min. N. and longitude 91 deg. 30 min. W. A number of vessels have reported from this position that the oil was seen bubbling on the surface, while the report on September 10, from the steamship "Comedian," described it particularly as coming up in three jets. It is generally described as dark yellow, sometimes so thick that a vessel passing through will hardly make a ripple on the water. The oil floats away from the source in large fields, but it absorbs oxygen from the air and evaporates quickly. On evaporating the oily residue of hydrocarbons disappears and the emulsion, mixing with the water, first has the appearance of slime which is generally reported as discolored water, and later it turns the water milky white, which appearance is often reported in the eastern part of the Gulf current and as far south as the Florida Reefs.

The Source.—The location at 27 deg. 30 min. N. 91 deg. 30 min. W. is nearly south of the Trinity Shoal from which it is distant about 120 miles, and the chart shows depths of 600 fathoms. The Continental Shelf, with a general southeastward dip, is 90 miles in width from the Coastal Plain to the edge of the Shelf, at a depth of 100 fathoms (600 ft.); in 25 miles from the edge, the bottom drops off to 600 fathoms (3600 ft.), and in 20 miles more to 1000 fathoms (6000 ft.). The source may be at any one of these depths between 100 fathoms and 1000 fathoms. . . .

Genesis.—The oils which are found on the borders of the Gulf and those which appear floating on the deep sea are so different in their characteristics that they seem to have been separated by nature into two classes, one having an organic and the other an inorganic origin.

The bituminous deposits along the shores, the methane of the mud lumps, the sea wax, the oil ponds, are probably all due to organic agencies. The vegetable and animal remains which have given rise to local deposits, the presence of the fucoids and diatoms in enormous quantities, which slowly decompose and sink into the oozes, the climatic conditions, and the temperature of the water, all contribute material for the change into hydrocarbons. But the oils in these deposits contain no soluble salts and no free sulfur. In some cases plants predominate in the formations, in others animal remains, and the resulting products vary as petroleum varies in different fields.

The floating oil in the deep water is probably of azoic origin. . . .

As the flow of oil at or near the same spot has been more or less continuous ever since the days of which we have any record, it is probable that there is an enormous oil pool underneath the Coastal Plain and the Continental Shelf of Louisiana and Texas, which lies at a depth of more than 2000 ft. At the time of the last subsidence of the crust, the impervious cover of the pool was probably borne down by the great weight of the superposed deposits until the cap rock was broken, allowing the continuous escape of some oil which had accumulated below that stratum. Under any circumstances, it would be easy and natural for the oil to pass up through the water to the surface and be dissipated, but when we find the oil rising through a great depth of water with such violence as to displace the water in jets, it is evident that the pressure of gas behind the porous rocks is enormous.

The oil deposits of Louisiana which are known to be under the Coastal Plain, and those which are apparently under the extension of the Coastal Plain into the Continental Shelf, either immediately preceded or immediately followed the salt and sulfur solutions; they are all sulfur oils and, below the oil horizons, the sand is generally filled with salt water. Sulfur deposits are due to the action of volcanic gases; hydrocarbons are derived largely from the igneous rocks; chemical reactions in volcanoes need the coöperation of water and, in fact, steam, charged with carbon dioxide and sodium chlorid, is the mainspring of all volcanic phenomena; the gases of an expiring volcano consist of vapor, sulfurous acid and sulfureted hydrogen, hydrochloric acid and chlorid of ammonium. All these conditions are favorable to the deposits of the

hydrocarbons which, associated as they are with volcanic and intrusive phenomena, are believed to be due to inorganic agencies.

It will be noted that Lieut. Soley in part ascribes the appearance of bodies of oil off the Louisiana coast to the escape of oil under great pressure along lines of structural weakness from a main reservoir below. This excellent paper was called to my attention only recently, though I have long been aware of the reports of sea captains concerning oil bodies on the Gulf and have long considered them evidence of the presence of oil and gas activities or disturbances beneath the sea bottom. In my opinion, the escape of these bodies of oil periodically must necessarily be ascribed to excessive gas pressure accumulating on a line of structural weakness in a main reservoir, so that when the pressure rises above or in excess of its overburden, it opens the reservoir and ejects a certain quantity of oil and gas until, automatically, it is closed again by hydrostatic pressure, to be again reopened at a later period, somewhat on the order of the intermittent geysers of Yellowstone Park. Similarly we know of oil wells flowing "by heads" at intervals of 5, 10, or more minutes, simply because of the fluctuating balance between hydrostatic pressure and gas pressure.

SOURCE AND ORIGIN OF THE SALT-DOME OIL

Owing to the fact that all our prospecting on the Gulf Coast has so far been confined to the upper surface of the salt domes, we know little of their complete structure. We have innumerable and conflicting theories as to the origin of the domes and of the oil found on them, but little positive knowledge. On one point, however, all geologists now agree, viz., that, as I contended in 1901, the salt domes are of secondary origin, and the oil was not formed in the beds from which it is now produced, but has migrated into them. Some believe that the oil originated fairly close to where it is now found, but others that it has ascended from a considerable depth. Many facts lead me to concur in the latter view.

When I began boring on Spindletop, in 1901, I never for a moment expected to find oil under the conditions which prevailed in Corsicana or the other stratified oil fields, for my exploratory work carried out previously on the barren salt domes of Louisiana had taught me that conditions were very different. I have always believed that the salt, gypsum, dolomite, etc., composing the dome are of secondary origin and that the oil and gas have migrated to their present position. In this connection, I had a long series of arguments⁵ with Prof. R. T. Hill in 1901,

⁵ My discussions with Hill have been fairly set forth by Harris. See G. D. Harris: *Rock Salt, Its Origin, Geological Occurrences and Economic Importance in the State of Louisiana*. *Louisiana Geological Survey Bulletin* No. 7, 1908, 65-68.

and it was only with difficulty that I convinced him of the existence of dome structure and of the secondary character of the dome-forming materials, facts which Hill and all other geologists now admit. In the present paper, therefore, I am advancing no new idea but am simply discussing and developing the views which I have held from the beginning.⁶

As already stated, when the oil reservoir on a dome is tapped, a large production is generally obtained, but this production in no case has proved of a permanent nature, but begins to decline after a certain time, be it a few days, a week, or longer. The reason for this is very apparent. The gas and oil being confined under pressure in cavernous dolomite, on being released comes out with much force, but, as soon as the pressure abates the flow of oil decreases in volume and ultimately stops.⁷ Putting the well under the beam may again increase production, but as there is no real oil sand, in the sense of the great sand encountered in West Virginia or Pennsylvania, no permanent results can be obtained or expected. Furthermore, the area of a true dome is very small, say between $\frac{1}{2}$ mile and $1\frac{1}{2}$ miles in diameter, and though in some instances considerable oil has been produced on the slope of a dome, as at Humble, most of the Gulf Coast oil has been derived from the cap rock or the irregular sands above it.

The gas pressures in many of the coastal fields are stupendous and have resulted in the destruction of many drilling rigs. At Saratoga, a gas pocket blew the tools from the well and formed a crater several rods in diameter, in which was swallowed up the wreck of the derrick and machinery; at Spindletop, one wrecked the machinery.

Disastrous blow-outs have also occurred at Humble, and in Belle Isle a gas pressure of over 1000 lb. was encountered in the salt itself. In the neighboring parish of Terrebonne, where no salt domes are known, enormous volumes of gas under high pressure have been discovered, permanent enough to warrant the laying of pipe lines to convey them to New Orleans, a project which is now in contemplation. In the typical salt-dome fields, however, the blow-outs are due simply to pockets of gas, and they continue only until these pockets are exhausted. With the exhaustion of the gas in the pocket, it is safe to conjecture that an equal volume of oil is permitted to creep upward and distribute itself along the easiest way of travel.

The well that encountered the great gas pressure in the salt at Belle Isle was drilled in 1907 by I. N. Knapp, through my instrumentality.

⁶ *Science*, New ser. (Aug. 30, 1901), 14, No. 348, 326-328.

⁷ There are records of a number of wells showing that after a lapse of a certain period they were found to be again producing, for a time, one or more hundred of barrels per day, thus proving that the oil traveled upward, refilling the exhausted locality.

This well, a partial record of which is given in *Bulletin* 429 of the United States Geological Survey, reached the depth of 3171 ft. From numerous horizons large quantities of rock-salt cuttings were brought out with the bailer, and these, when dumped on the derrick floor, would jump like firecrackers or popcorn, leaving the floor covered with a scum of oil and paraffin. Fig. 3 is an enlarged photograph of a specimen of this salt, showing the inclusions of oil and gas. Indeed, the surface of the adjacent slush pond, 100 ft. in diameter, where the returns of the well were dumped, was covered during a cold spell with about an inch of solid paraffin. At about 2700 ft., the drill apparently passed out of salt



FIG. 3.—OIL AND GAS INCLUSIONS IN SALT CRYSTAL.

into a calcareous rock like anhydrite and magnesite, and at 3171 ft. about 3 bbl. of reddish oil of about 40° Bé. gravity were secured while an effort was being made to bail the well (a change in color from canary yellow as at the upper surface was noted) when the casing collapsed and the hole had to be abandoned. The presence of gas under such great pressure in the salt itself down to 2700 ft., and of oil below, proves to my mind that these hydrocarbons must have been forced up from a considerable depth.

The initial source of the petroleum cannot be definitely determined at the present time, though in my opinion there are many facts, in addition to those already cited, which indicate that it is partly or largely of inorganic origin and that the domes themselves are certainly due to igneous forces. The sulphur present in the cap rock of the domes, occasionally in great quantity, cannot be satisfactorily explained except as the result of dying vulcanism or solfatara fumarole action. At Belle Isle, a crevice in the salt mass 590 ft. deep is filled with sulphur-impregnated rock³ and at Sulphur, Bryan Heights, and Damon Mound, several

³ A. F. Lucas: Review of the Exploration at Belle Isle, Louisiana. *Bulletin* No. 129 (Sept., 1917), 1435-1447.

hundred feet of limestone or gypsum, richly impregnated with sulphur, are found. The suggestion that the sulphur is derived through the reduction of gypsum at moderate temperatures cannot be substantiated in the chemical laboratory, where a temperature of many hundred degrees Centigrade is required for the reduction of gypsum.

The drilling of almost every dome has also disclosed hollow tubular, or worm-shaped, concretions composed of pyrite. The presence of the small openings in the center of these tubes suggests that they were formed by hot sulphur gases forcing their way upward, which in cooling condensed and expanded and left the sulphur and iron in capricious forms resembling worms. The presence of sulphides of other metals—galena, sphalerite, chalcopyrite, etc.—also indicates connection with igneous forces.

Dr. Eugene M. Coste,⁹ the exponent of the volcanic theory of the origin of oil, boldly takes the ground that petroleum is of inorganic origin and is the result of solfataric volcanic emanations. Dr. Coste reasons that animal organisms entombed in rock could not produce oil by distillation and that vegetable remains decompose into carboniferous matter, such as peat, lignite, coal, marsh gas, etc. Moreover, the distillation of organic remains takes place in nature soon after their deposition and they are thus lost largely as methane and carbon dioxide. The irregularity of gas pressures is also cited as evidence of the deep-seated origin of oil, for if gas pressure is really hydrostatic in character it should be fairly regular. On the other hand, in volcanic regions, gaseous, liquid and solid hydrocarbons, carbon dioxide, salt, and other chlorides, hydrogen sulphide, sulphur, gypsum, and hot calcic and siliceous waters are found. It is well established that the salt domes themselves are made up of secondary material which has been brought up along lines of weakness from great depth, and as the oil and water are generally quite hot it is entirely reasonable to suppose that they were also brought up from below. The high gas pressure encountered, far greater than hydrostatic pressure, also indicates deep-seated origin.

It is a well known fact, conceded by the best authorities, that petroleum occurs in rocks of all ages and nearly all kinds. I recently had occasion to examine, through the courtesy of Dr. Coste and Dr. Ledoux, a quartz crystal containing inclusions of oil and gas (Fig. 4). This occurrence was described in 1898 by Reese,¹⁰ who states that Sir Humphrey Davy,¹¹ in a study of the fluid contents of cavities in rocks, mentions a

⁹ E. M. Coste: Volcanic Origin of Natural Gas and Petroleum. *Journal, Canadian Mining Institute* (1903), 6, 73-128.

¹⁰ C. R. Reese: Petroleum Inclusion in Quartz Crystals. *Journal, American Chemical Society* (Oct., 1898), 20, 795-797.

¹¹ Sir Humphrey Davy: On the State of Water and Aëriform Matter in Cavities Found in Certain Crystals. *Royal Society of London, Philosophical Transactions*. 1822. 367-736.

single instance in which naphtha was found in a quartz cavity. Davy states that "the quartz crystals containing the oil and gas inclusions were found at Diamond Post Office, near Gunterville, Marshall County, Ala., near the Tennessee line. The inclusion presents the appearance of petroleum, in that it has the yellow-green fluorescence. A crystal from the same locality was crushed on filter paper which, having absorbed the oil, showed grease spots and gave the characteristic odor of petroleum and burned with a smoky flame. Another evidence of the nature of the liquid is that petroleum occurs in the neighborhood where the crystal was found."



FIG. 4.—OIL AND GAS INCLUSIONS IN QUARTZ CRYSTAL. $\times 25$.

G. S. Rogers,¹² in his discussion of Matteson's paper on oil prospecting in the Gulf Coast country, mentions "the discovery during the past summer of volcanic ash in the sediments around one or two of the domes; of a rock resembling a porphyry in a well at Damon Mound; and an undoubted igneous plug about 50 miles north of the salt-dome belt." These new discoveries lend added weight to the igneous theory, and the close association of oil with igneous rock in the neighboring regions of Mexico and Cuba should not be overlooked.

The probability that the salt-dome oils, as well as the salt domes themselves, are a product of volcanic forces leads me to suggest a hypothesis involving the existence of laccoliths under the domes. According to the late Dr. G. K. Gilbert, laccoliths in the Henry Mountains of southern Utah have produced similar dome-like elevations at the surface. The molten rock has risen through a vertical pipe or fissure, but being unable to burst across the superincumbent bed has insinuated itself between the strata and by lifting them up has caused a doming visible at the surface.

¹² *Bulletin* No. 136 (April, 1918), 828.

This explains the known structure of domes more adequately than would a sill or plug of igneous rock, such as is found in the Mexican fields.

As we are totally in the dark as to the position or age of the laccoliths their form, composition or depth, that may have given rise to the domes, it is impossible to present in detail their relations with the salt, though I have attempted to do this in the accompanying hypothetical sketch

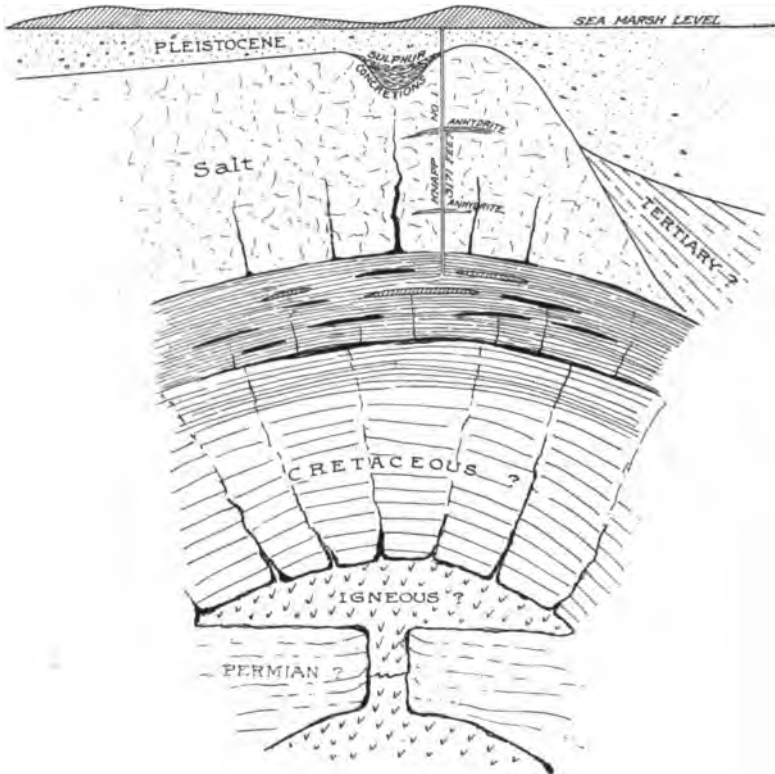


FIG. 5.—HYPOTHETICAL SKETCH SHOWING POSSIBLE RELATIONS OF BELLE ISLE, LA., DOME.

(Fig. 5). This represents a cross-section of the Belle Isle dome which is very evidently located on a prominent line of structural weakness. This line is marked by the sulphur-filled channel in the salt above and by the presence of oil and gas under great pressure in the salt nearer the base of the dome. Although the exact character and age of the strata beneath the salt but above the supposed laccolith are unknown, it is probable that they are domed in conformity with the known upper surface of the salt mass.

METHOD OF EXPLORATION PROPOSED

Whether the foregoing hypothesis of the origin of the domes is correct or not, the fact remains that the domes are there and it is for us to make

the best of it. When I drilled on Spindletop in 1900, I was told by some of the best geologists in the United States that this slight elevation and accompanying phenomena did not prove it a dome and had no significance, and that I was wasting my time and money; and similarly today many geologists doubtless disagree with my views that further supplies of oil are to be found in the domes at greater depth. However, the various conflicting theories and opinions that have been offered by leading geologists since the problem sprang into existence in 1901 embolden me to suggest that theories be ignored and that a thoroughly practical test be made. We know positively only that the Coastal Plain is covered with Pleistocene sediments and that at points beneath it there exist salt domes carrying oil. As to how the domes originated or where the oil came from, we know nothing. I will therefore put my suggestions on a practical basis in the hope that if they are acted upon some definite knowledge of practical value will result.

Although several deep wells have been drilled on salt domes, none of them was located with reference to its value as a deep test. A well at Humble penetrated salt to 5300 ft., but it was intended to find oil at moderate depth and was not located with reference to lines of structural weakness, as a deep test should be. Similarly, many deep wells have been drilled into the sediments off the sides of various domes and have found no oil, but this, of course, proves nothing. At Damon Mound, for example, a well has just been drilled to 4620 ft. in order to test the theory that the big pool would be located off the dome at a deep level, but this well has found only some oil seeps and water. The presence of water in the sediments on the flanks of the domes is to be expected, while the chance of finding water in a well drilled in a central location on the dome proper would be either greatly minimized or disappear altogether.

Of all the domes with which I am familiar, Belle Isle seems to offer the greatest promise of rewarding a deep test. This dome rises prominently out of the marshes that surround it for many miles and is the farthest southeast of the series. As already stated, there is a pronounced line of weakness crossing this dome, as evidenced by a sulphur-filled channel in the salt, some 590 ft. deep. Far down in the salt itself, oil and gas under great pressure are found and the largest quantity was encountered at the greatest depth reached. It is very unfortunate that Mr. Knapp's well could not have been drilled deeper. At the beginning of operations, Mr. Knapp expected to go only about 1800 ft. and used a small rotary and standard rig. During the drilling, he found reason to become interested in reaching a greater depth and by great skill and careful management succeeded in reaching 3171 ft., though, owing to the heavy gas pressure, he was unable to secure good samples of the rock penetrated below about 2700 feet. At 3171 ft., he bailed out 3 bbl. of reddish paraffin oil of about 40° Bé. gravity, when the casing collapsed and the well had to be abandoned.

Another favorable indication at Belle Isle is the presence of crystals of sphalerite, galena, barite, native sulphur, etc. These crystals are sharp and well developed and have evidently been formed in place, for they show no signs of erosion. Although sulphur also occurs in great quantity at Bryan Heights, Sulphur, and Damon Mound, which presumably indicates that these domes are also located on partly open fissures, the actual presence of oil and gas in the salt itself at Belle Isle leads me to consider this dome most favorable for a deep research well.

It is, of course, impossible to state even approximately how much deeper a well would have to go at Belle Isle in order to tap the main reservoir of oil. Oil in paying quantity might be found only a few feet below where Knapp stopped and where the signs were most promising, though on the other hand it may lie several hundred or a thousand feet deeper, or more.

It has never been possible to drill on the Gulf Coast with the standard tools so extensively used in many oil fields, owing to the drift and quicksand encountered and to the probability of blow-outs. At the time I drilled on Spindletop, the rotary method was in its infancy and during the past 15 years enormous improvements have been made. Extremely heavy tools are now manufactured and many extra appliances have been devised. The rotary or hydraulic machine of the early days of my pioneer work compares with the rotary of today as the early steam-engine compares with our modern triple-expansion engines.

In order to make as complete a test as possible, one should be prepared to drill a deep record well, even though on Belle Isle oil may be struck a short distance below where Knapp stopped. The project of drilling, if necessary, a 7000-ft. well is today perfectly feasible, for the Hope Natural Gas Co. of Pittsburgh is now drilling a well in West Virginia which on Feb. 19, 1918, had already reached a depth of 7363 ft. For a deep well on Belle Isle, I would recommend a specially constructed hydraulic rotary machine for the first 4000 or 5000 ft., with extra heavy cable tools to proceed farther, if indications warrant it.

The drilling of a well of this character should be carried on in co-operation with a competent geologist of the United States Geological Survey, who could examine samples of the rock, oil, gas, and water encountered, and test the temperature at various depths.

In conclusion, I may state that I have no financial interest in exploiting this enterprise on Belle Isle or elsewhere, and have simply set forth my opinion in the hope that my early discoveries on this island and on the Coastal Plain may be still further extended for the benefit of any who care to accept the hazards involved, and for the advancement of science.

DISCUSSION OF THIS PAPER IS INVITED. It should preferably be presented in person at the Colorado meeting, September, 1918, when an abstract of the paper will be read. If this is impossible, then discussion in writing may be sent to the Editor, American Institute of Mining Engineers, 39 West 39th Street, New York, N. Y., for presentation by the Secretary or other representative of its author. Unless special arrangement is made, the discussion of this paper will close Oct. 1, 1918. Any discussion offered thereafter should preferably be in the form of a new paper.

Losses of Crude Oil in Steel and Earthen Storage

BY O. U. BRADLEY,* E. M., MUSKOGEE, OKLA.

(Colorado Meeting, September, 1918)

THE extent of losses, due to evaporation, sediment, and water, in crude oil stored in steel tanks, is a very interesting question, and particularly so at this time, when every reasonable measure should be employed to eliminate all possible losses of this important natural product. Available information on this subject is incomplete; *e.g.*, during the development of the Cushing Field, considerable surplus oil was stored in steel tanks, but from time to time, owing to changes in weather, some losses by evaporation and short storage room on the leases, these tanks were topped out, thus rendering inaccurate any system designed to determine the average rate of evaporation or other losses of the oil over a given period. Furthermore, the losses, as shown by the records at the time, as a result of hasty gages, failed to take into account the temperature and gravity of the oil. Losses may be classified roughly as occurring from evaporation, presence of sediment and water, and leakage. The coefficient of expansion and contraction of crude oil, in relation to temperature conditions, is of material importance; also, the rate of evaporation is dependent upon the gravity of the oil, as the escape of the lighter hydrocarbons in fresh Cushing oil, of from 40 to 42 gravity, on a warm day is considerable, and from available records of temporary storage, it is safe to assume that a loss of 1 to $1\frac{1}{2}$ per cent. in volume will easily occur in light crude oil of Cushing grade over a period of 6 months, including the summer season. The presence of sediment, water, and other impurities, in the oil will also cause more or less deterioration in quality, particularly when the fresh production is run direct from the gage tanks, or from the wells on the lease to steel storage, as is often the case when an oil field is being rapidly developed. The bad oil will settle to the bottom of the tanks and may be determined by thieving and running a centrifuge test on the sample. The amount of water in the oil depends entirely on the conditions under which it is produced. Sometimes in large producing wells, with heavy gas pressure, some water may come in with the oil, particularly if the well has been drilled to the top of a water sand. Under these conditions, cut oil is often produced, which, if not settled out, is carried over into the steel tanks.

The losses by leakage in steel tanks are difficult to determine, for

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the reason that some tanks are built better than others. Contractors are required to turn out work that will reduce the losses due to leakage to a minimum, but in hurried building, necessitated by emergency conditions in a rapidly developing oil field, the character of the work is often not up to standard.

A record of losses, due to sediment and water, on Cushing stored oil, covering a period of from 5 to 7 months, is shown in Table 1.

TABLE 1.—*Gage Showing Sediment and Water*

Tank No.	Gage		Sediment		Water		Total Per Cent.
	Date of Filling	Date of Test	Barrels	Per Cent.	Barrels	Per Cent.	
1	55035.26 5/31/1914	54810.47 1/31/1915	970.29	1.7	513.18	0.9	2.6
2	55603.76 6/9/1914	54470.27 1/31/1915	665.04	1.2	513.39	0.9	2.1
3	54894.52 6/18/1914	54140.57 1/31/1915	1045.83	1.9	512.25	0.9	2.8
4	54907.10 6/28/1914	53816.85 1/31/1915	970.68	1.8	284.98	0.5	2.3
5	54478.39 7/15/1914	54102.88 1/31/1915	744.35	1.3	591.64	0.1	2.3
6	54982.84 8/9/1914	54643.34 1/31/1915	897.30	1.6	591.80	0.1	2.6
7	54653.97 6/15/1914	53937.81 1/31/1915	862.50	1.5	431.25	0.7	2.2
8	54931.53 6/30/1914	53724.89 1/31/1915	843.83	1.5	555.23	1.3	2.8
9	54766.65 7/4/1914	53812.81 1/31/1915	766.90	1.4	630.41	1.1	2.5
10	54784.53 7/17/1914	53767.56 1/31/1915	653.25	1.2	440.27	0.8	2.0

No record of temperature or gravity was kept, and therefore it is not possible to give the evaporation. The possible leakage was not considered.

In measuring the oil in steel tanks, in order to determine losses, the depth is taken at the two hatch holes by steel tape, and an average is computed from the results. This steel tape should be graduated to $\frac{1}{16}$ in. and a 5-lb. plumb-bob is preferable to one of lighter weight.

It is known that losses in earthen storage are high, but to the author's knowledge there was but one case in the Cushing Field where an attempt was made to determine such losses, and then no temperatures or gravities were recorded. The reservoir used was prepared as carefully as possible in the face of the emergency due to the necessity of providing for a large production on the property. The banks were tamped, the inner

surface puddled and the whole reservoir roofed over shortly after filling. The oil was run in during the hot summer months and removed before cold weather set in. The record on filling, removal and percentage of loss is as follows:

	Barrels
Time of filling and total number of gross barrels run in	
May 6 to June 28, 1914, inclusive.....	35,039.54
Removal of merchantable oil, Aug. 9 to Sept. 2, 1914..	28,651.10
Loss.....	6,388.44
Percentage.....	18.2

In the case of Healdton oil, which is of heavier gravity and somewhat different in character, the following is a record of a loss on three steel tanks, two of which were filled and one partly filled direct from the wells on the lease as the oil was produced. The time of filling these tanks covers a period of 8 months, the months and the quantities of oil run into them being as follows:

Month	Total Barrels
Aug., 1916.....	10,463.34
Sept., 1916.....	17,571.74
Oct., 1916.....	22,964.93
Nov., 1916.....	20,803.99
Dec., 1916.....	20,441.20
Jan., 1917.....	15,432.25
Feb., 1917.....	9,627.32
To Mar. 12, 1917.....	3,220.15
	120,524.92

A portion of the last run of oil was used to top out the two full tanks, so that on March 12, the measurement and total gross barrels in each tank were as shown in Table 2.

TABLE 2

Tank No.	Measurement		Gross Barrels
	Ft.	In.	
1	29	10	52,806.36
2	29	4 $\frac{5}{8}$	52,014.52
3	8	11 $\frac{1}{4}$	15,704.04
			120,524.92
Gravity of the oil, 30			

The quantity of oil checks exactly with the total quantity run, as shown above, because no gage was taken other than the total monthly amount run into each tank, which was always calculated from the difference between the previous month's measurements and those of the month for which the record was desired.

The record on the purchase of the oil, after tanks had been restrapped, with tests for sediment and water, is shown in Table 3.

TABLE 3

Tank No.	Date of Test	Measurement		Gross Barrels
		Ft.	In.	
1	June 30, 1917	29	10½	52,880.24
		Sediment..... 1	3½	2,038.48
		Water..... ..	2½	358.17
		Merchantable oil.....		50,483.59
2	June 17, 1917	29	4¾	52,051.46
		Sediment..... 1	....	1,754.33
		Water..... ..	2¾	389.11
		Merchantable oil.....		49,908.02
3	June 13, 1917	8	11¾	15,722.54
		Sediment..... 4½	....	647.24
		Water..... .. 1	.,.	143.35
		Merchantable oil.....		14,931.95

		Per Cent.	
Tank No. 1—Sediment.....		3.85	
Water.....		0.67	
			4.42
Tank No. 2—Sediment.....		3.37	
Water.....		0.74	
			4.11
Tank No. 3—Sediment.....		4.11	
Water.....		0.91	
			5.02

These losses are high, I believe, as undoubtedly some of the heavy oil in these tanks could have been sun cured and recovered; and, furthermore, it was flush production run to steel, which is not the usual practice in the storage of crude oil.

Table 4 gives a record on six 55,000-bbl. tanks in the Healdton Field, showing total losses, due to evaporation, leakage, and bad oil, over a period of 11 months:

TABLE 4

Tank No.	Standard Temp. and Gvty. Correc. Vol., March 1, 1917	Correc. Vol., Jan. 31, 1918	Leakage and Evap., Barrels	Sediment and Water, Barrels	Total Loss, Per Cent.
1	52,722.46	52,395.13	327.33	1,241.38	2.97
2	52,428.09	52,162.95	265.14	1,088.02	2.58
3	53,000.32	52,122.02	878.30	1,202.78	3.92
4	51,452.78	50,724.22	728.56	1,049.89	3.40
5	53,485.61	53,086.59	399.02	1,294.89	3.16
6	53,605.75	53,064.02	541.73	991.12	2.85

The above results do not show any considerable uniformity as regards evaporation and leakage. I believe this is due, in large measure, to the variations in leakage. An examination of the conditions of these tanks in the field shows the familiar oil stains on their sides. This is particularly true of tanks 3, 4 and 6, while others are almost free from stains of this character. The quantity of the bad oil in the tanks seems to average up to about what would be expected in crude oil which has been in storage for a period of 11 months. Inasmuch as the water and sediment were not separately determined in the tests, it cannot be stated what proportion of these two materials were present. Under treatment or steaming, a certain percentage of what is termed bad oil could be recovered. The general average percentage of loss, due to deterioration in quality of oil, leakage, and evaporation in these tanks was, therefore, 3.15 per cent. for the period above specified.

DISCUSSION OF THIS PAPER IS INVITED. It should preferably be presented in person at the Colorado meeting, September, 1918, when an abstract of the paper will be read. If this is impossible, then discussion in writing may be sent to the Editor, American Institute of Mining Engineers, 20 West 39th Street, New York, N. Y., for presentation by the Secretary or other representative of its author. Unless special arrangement is made, the discussion of this paper will close Oct. 1, 1918. Any discussion offered thereafter should preferably be in the form of a new paper.

The Automatic Separation of Solution from Solids in the Hydrometallurgical Treatment of Ore Pulps

BY BERNARD MACDONALD, SOUTH PASADENA, CAL.

(Colorado Meeting, September, 1918)

THE writing of this paper was prompted by the discussion by H. M. Chance, in the April *Bulletin*, of the paper written by Thomas M. Chance which appeared in the February *Bulletin*, and by the remarks of the Editor in which he stated that while the matter contained in discussion did not refer to the original paper it "was presented as of interest to the operators of cyanide and other lixiviation processes dealing with fluid mixtures of varying specific gravity."

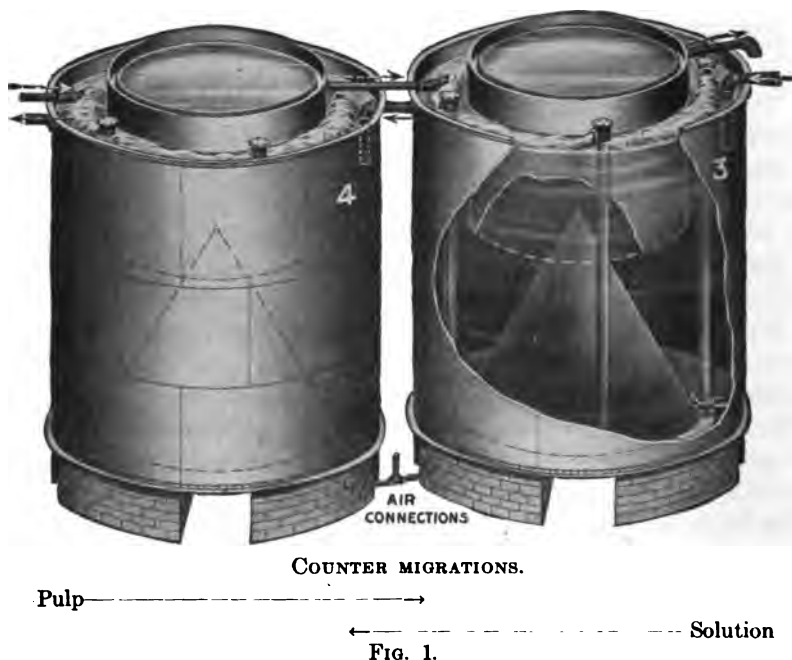
For some years past the principle enunciated in the discussion referred to has been known to the writer and demonstrated by him to be an efficient and economical way of separating water or solution from solids in the cyanidation, lixiviation or acid leaching of ore pulps. In utilizing this principle in commercial practice he has invented a method whereby not only the separation of solution from solids may be effected in any given tank, but also the *counter migration* of the solids and solution may be effected continuously through a series of tanks in which the hydrometallurgical treatment of ore pulps is being carried on.

In effect this method is analogous to the counter-current system, but is different physically in that it is carried on throughout a series of tanks on practically the same level, continuously and automatically, by hydrostatic pressure and gravity-flow, without the aid of intervening pumps or elevators, at the same time that agitation is being carried on in the same tanks.

In the Parral system, agitation is effected in tanks by a number of air lifts of comparatively small diameter through which the pulp is continuously transferred from the bottom of the tank and spouted horizontally on top of the charge. The spouting force of the several streams thus discharged maintains a rotary flow in the pulp charge which extends from top to bottom of the tank. This continuous transfer of pulp and the spiral flow from top to bottom of the tank maintains the pulp constituents in uniform proportions and meets the requirements of efficient treatment in a most economical manner. The quantity of compressed air required is very small, as the pulp is not lifted but simply trans-

ferred from the bottom to the top of the tank charge under hydrostatic balance.

To illustrate the apparatus and explain the results obtained, Fig. 2, 3, 4, and 5 are submitted. These figures represent two views each of two adjoining tanks taken from the middle of any series of tanks in which the continuous treatment of pulp is being carried on. Fig. 2 and 3 show a vertical cross-section through the center of two tanks equipped with my apparatus, along line *AA* in Fig. 4 and 5, which represent the top view of the same two tanks.



As shown in the figures, a diaphragm *C* is mounted concentrically in the upper portion of the tanks. This diaphragm is cylindrical in shape, open at the top and bottom, and is of such width and depth as required by the function it is to perform. The pulp is continuously agitated in the annular space between the diaphragm and the sides of the tank by transfer pipes to which compressed air is conveyed through pipes *f*. At the bottom and below the lower edge of the diaphragm is the separation zone where the solids in the pulp settle by gravity and fall on the sloping sides of the cone *b* over which they gravitate to the intake ends of the transfer pipes through which they are continuously transferred and spouted on top of the tank charge in the agitation circle. Above the separation zone, the water or solution rises clear within the diaphragm, and by the hydrostatic pressure of the pulp undergoing agitation the clear

solution is raised to a height above the level of the pulp commensurate with the depth of the sides of the diaphragm.

As an example, if the pulp being agitated contained 2 parts by weight of solution to 1 part by weight of solids, it would have the specific gravity of, say, 1.26, (depending on the specific gravity of the solids) or, about one and one-quarter times the weight of the same volume of water. Therefore, if the sides of the diaphragm extend, for example, 9 or 10 ft. down into the pulp, the weight of the pulp would raise and balance a

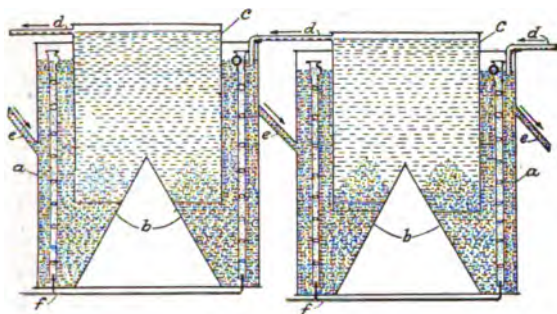


FIG. 2.

FIG. 3.

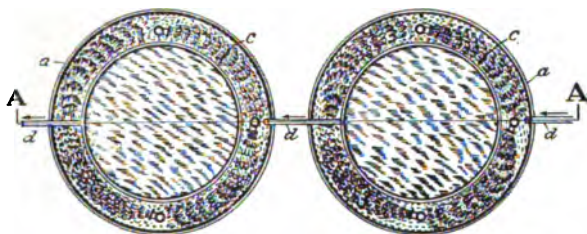


FIG. 4.

FIG. 5.

column of clear solution within the diaphragm to a height of more than 2 ft. above the level of pulp in the agitation circle. The separation of the solution from the solids takes place rapidly in the separation zone at the foot of the diaphragm, probably due in a considerable degree to the centrifugal force set up by the rotary flow of the pulp in the agitation circle. At any rate, clear solution separates from the pulp mass in this region and rises rapidly and continuously within the diaphragm from the top of which it is taken off through pipes *d* and delivered into the pulp being agitated in the next adjoining tank, and so on until from the head tank of the series the solution goes to the clarifiers to remove any fine slime that may be carried over in suspension, and thence to precipitation.

The series of tanks in which the treatment is carried on is set so that each tank from head to tail of the series is 6 in. below the level of the tank preceding it. This height is quite sufficient to overcome the flow friction

of the pulp as it goes from tank to tank through pipes *e*. The last two tanks of the series may be specially arranged so that the pulp may be thickened to a very high density before it is discharged to filter press or dump as conditions require. In this way, the counter migration of the solids and solution is brought about automatically and continuously through any number of tanks equipped as shown in the illustrations. The precipitated cyanide solution, which is added to the last tank of the series, flows from tank to tank toward the head of the series, dissolving the metals from the solids with which it is agitated as it goes. The solution thus becomes enriched as it goes from tank to tank until it flows from the head tank for precipitation, while the solids being carried from the head to the tail tank of the series become poorer and poorer until they are discharged barren from the tail tank.

The same principle may be used in the acid leaching of copper ores, but the tanks and the transfer pipes used for this purpose are made of wood in order to be acid proof. This method obviates the use of pumps between the tanks, which give great trouble in handling acid solution.

The agitation of the pulp may be carried on within the diaphragm, leaving the annular space outside the diaphragm for the rise of the clear solution. I have designed this latter method for a plant having Pachuca tanks, but the first described method may also be installed in Pachuca tanks to advantage because the clear solution may be lifted to any height which allows a series of tanks set on a level to be operated without the intervention of pumps.

Some time ago I suggested to the operator of a plant of Pachuca tanks that he equip the tanks with the apparatus I have described, but he was skeptical that water could be made to rise above its own level so as to flow from tank to tank as I described.

A 12-ft. length of stack was available and this was suspended in the tank to a depth of 10 ft. below the level of the pulp being agitated. In 2 hr. clear solution was overflowing the top of the pipe, which was 2 ft. above the pulp level, a continuous overflow as from an artesian well.

In the hydrometallurgical treatment of ore pulps, the principle developed as described and applied will be found to be an important forward step. The cost of installation is small and the cost of operation is nothing.

Principles and Problems of Oil Prospecting in the Gulf Coast Country

Discussion of the paper of W. G. MATTESSON, presented at the New York meeting, February, 1918, and printed in *Bulletin* No. 134, February, 1918, pp. 429 to 468.

WILLIAM KENNEDY, Fort Worth, Tex. (written discussion*).—In his discussion of this paper, Mr. Sherburne Rogers offers voluminous figures to show that the salt forming the cores of the various domes could not have been derived from sea water, and gives as an illustration the immense quantity of water required to form the salt found in the Humble dome. He refers to the theory advanced by van der Gracht apparently in support of this contention, and claims to have disposed of the views held by some that the domes were, in a great measure, formed by lateral secretion.

Van der Gracht says the immense salt plugs found throughout North Germany and other countries in that region were apparently formed by orogenic movements acting upon what he calls the Mother Bed of Salt, which he gives a thickness of about 1000 ft., and an extent of several thousand square miles. The age of this "mother bed" is given as Permian. Harris, in addition to his growing-crystal theory, also says probably a great portion of the salt found in the Coastal domes may have been derived from the salt water of Permian time. Both of these theories require an abundance of water, and consequently oppose Mr. Rogers' idea that the immensity of water required disproves the formation of the salt from that source.

I do not suppose, however, that either van der Gracht or Harris absolutely limits his view to the Permian as being the only source from which the salt could have come, but would probably agree to consider any other age as being the beginning. Although the Permian is very strongly represented throughout North Texas, we have none anywhere throughout the region from which the salt may be considered as having been derived. Many deep wells have been drilled along the eastern outcropping of the Carboniferous and each has passed directly from Cretaceous to Carboniferous formations. Thus we may eliminate the Permian as a source of salt in this region. But, although the Permian may be absent, we have with us the Carboniferous with probably a thickness of 3000 to 4000 ft., and something like 3000 ft. of Cretaceous, to say nothing of approximately 8000 ft. of Tertiary and later beds, all of which, if we may judge by the quantity and density of the waters obtained from the numerous wells drilled, carry immense quantities

* Received Apr. 15, 1918.

of salt disseminated throughout the beds; considerably more than necessary to form the cores of a great many more domes than at present known.

It is generally admitted that the presence of so much salt in the Permian is due to the presence of marine water, together with an arid climate in which evaporation was rapid, and due to this more or less concentration the salts found are localized into ponds or basin-like depressions. This condition may have occurred in Carboniferous or Cretaceous times, and even in the Tertiary, and owing to the concentration of the salt not so much water may have been required as Mr. Rogers appears to think. Solutions so concentrated as to cause deposition are quite different from seawater. The structure of the salt found in the Coastal domes shows it to be a secondary formation and has none of the earmarks of primary deposition. This, in itself, shows the elaborate calculations made by Mr. Rogers to be worthless and have no bearing whatever on the origin of the Coastal salt domes.

While the probabilities are very much against the existence of any "mother bed" of salt anywhere within this region, we may yet consider the fact that throughout it the deposits, from Carboniferous up, are all highly saliferous and that through the long migrations of the waters they, in all probability, became highly concentrated solutions carrying both lime and salt. As the domes appear to lie along lines of structural weakness, it may be possible that these, in some degree, represent the conditions required by the van der Gracht idea and may possibly have formed the basins or vents in which the salt was concentrated, and thus formed the dome. Under these conditions, not so very much water would be required. It may also be pointed out that the increasing size of the dome by the growth of the crystals would, of necessity, require concentrated solutions in connection with the core, as crystals, to grow, would require material, and this material would have to be obtained from the brines traveling through the adjacent formations. This would practically be lateral secretion.

Mr. Rogers appears to place much reliance upon the presence of the so-called paraffin dirt as an indicator of the presence of oil. It would occupy too much time and too much space even to enumerate the localities in which worthless wells have been drilled upon this symptom of the presence of oil. It has been given special prominence in wild-cat prospectuses over and over again, and incidentally over and over again the unfortunate investors' money has been lost. In many of the important pools, the presence of this so-called indication has not been noted, but it is present in many localities where drilling has shown neither oil nor gas, except in very insignificant quantities.

The Theory of Volcanic Origin of Salt Domes

Discussion of the paper of E. L. deGolyer, to be presented at the Colorado meeting, September, 1918, and printed in *Bulletin* No. 137, May, 1918, pp. 987 to 1000.

J. A. UDDEN,* Austin, Tex. (written discussion†).—I have read Mr. E. L. deGolyer's paper on The Theory of Volcanic Origin of Salt Domes, with a great deal of interest. It seems to me a very able summary and discussion of the various theories set forth to account for the origin of our salt domes on the coast. It has always appeared to me that what we need is more observations on the facts involved and I regret very much that so far we have not been able to devote much time to the study of our salt-dome fields on the coast in this State. One feature that I do not find mentioned in Mr. deGolyer's paper is the so-called "cap rock" overlying the salt. The nature of this rock seems to vary from a coarsely crystalline limestone to a fine-grained limestone containing sand and in which the limestone seems to be interstitially introduced material. We should be prepared to accept, if necessary, more than one theory. To my mind, the igneous theory and the artesian theory, if I may so call it, may very well both be true. The "squeeze" theory and the artesian theory may, it seems to me also, jointly explain the phenomena. Neither the volcanic nor the salt "squeeze" theory explains the presence of the cap rock. The latter certainly does not explain the extensive sulphur deposits which occur in association with the cap rock. Whichever additional theory will be found best to explain the salt-dome structures, when we shall know them better, it seems to me that the theory first advanced by R. T. Hill and later elaborated by G. D. Harris, is not likely to be entirely replaced. Whatever cause has first set into action an upward circulation of gases and liquids in our salt domes, it seems to me that to a gentle circulation of the kind postulated by their theory is to be ascribed the uppermost and the later phenomena in our salt domes on the coast, with which we are most familiar; such as the cap rock, the sulphur, and the gypsum and anhydrite deposits.

* Director, Bureau of Economic Geology and Technology, University of Texas.

† Received May 27, 1918.

An Interpretation of the So-called Paraffin Dirt of the Gulf Coast Oil Fields

Discussion of the paper by Albert D. Brokaw, to be presented at the Colorado meeting, September, 1918, and printed in *Bulletin* No. 136, pp. 947 to 950.

W. E. WRATHER, Wichita Falls, Tex. (written discussion*).—The appearance of Mr. Brokaw's paper dealing with the chemical composition of "paraffin dirt" will be welcomed by oil geologists who have worked in the Gulf Coast district. It is to be hoped that it will lead to a discussion of the subject which will throw some light on the relation this peculiar substance bears to the occurrence of oil deposits.

The problem of locating oil pools in advance of drilling is at the best a very intangible matter in the district along the Gulf Coast, and it is therefore desirable to make the most of any clew which may be of the least assistance to this end. Geologists have been familiar with "paraffin dirt" for a number of years, and have informally discussed its value as a surface indication of oil. But doubtless owing largely to the fact that they have been unable to define its exact composition, very little information has appeared in print on the subject.

The presence of this baffling and somewhat indeterminate substance is now quite generally accepted as one of the most reliable indications of a gas seepage. The question is whether paraffin dirt necessarily indicates that the escaping gas is an emanation from an oil deposit, or whether it merely indicates that marsh gas (methane) has here escaped from its source in the abundant decomposing vegetation entombed in the sediments of the old Mississippi Embayment, and the Gulf Coastal Plain.

The presence of this material has been relied upon to a great extent, both by oil producers and geologists, in the location of wildcat wells, since the discovery that it was associated with gas seepages. It is quite true that other surface indications were often present at such localities, but if, in addition, paraffin dirt could be found in the vicinity, this fact was accepted as the final justification for drilling a test well, despite the fact that no one seemed to understand its chemical composition or to know why it should be associated with oil. In fact, for a long time it has generally been accepted that the name is a misnomer, that very little, if any, paraffin is present in it, or, for that matter, any other known fraction of crude oil.

The name first appeared following the early development of Batson. It was applied to a gummy, reddish-colored bed of this substance found

* Received June 1, 1918.

on Batson Prairie, which had a fancied resemblance to true paraffin such as accumulated in oil lines and well tubing in the older Eastern fields. It was found that the material would burn, which further confirmed the belief that it was paraffin. Indeed, it is not strange that on the above criteria, this name should have been chosen, for there is often an undoubted resemblance in general appearance to paraffin. All trace of this deposit at Batson has long since disappeared.

The writer's personal opinion has been that the peculiar "rubbery" characteristic of paraffin dirt might possibly be due to colloidal silica, brought up in solution from below through the agency of hydrogen sulphide gas. This gas is commonly present in the Coastal oil pools, and is precipitated at the surface as an impregnation of the soil, perhaps owing to the loss of gas, and to the precipitating properties of humic acids derived from decomposing vegetable matter. Whether or not this was a tenable premise on strictly technical grounds has been a question, as no attempt was made to work out a chemical formula to fit the case. The idea merely took form as the result of numerous observations of the conditions under which the deposits were found.

These conditions seem to necessitate a moist, humid climate, and the presence of vegetable matter. The writer has examined gas escapements in the semi-arid region of west and southwest Texas, several of which have since been found to be associated with oil or gas, but nowhere in this area has he ever seen anything to resemble paraffin dirt. The character of the escaping gas in those regions did not apparently differ from that found in East Texas and Louisiana seepages which were accompanied by such deposits. It seems to be true also that "paraffin" dirt will not accumulate where gas escapes through water, provided the water covers the gas escapement most of the time. Repeated attempts to find traces of it in the bottom of pools through which gas was boiling incessantly were invariably unsuccessful. Sulphur gases, escaping through permanent pools of water, however, often leave a black or bluish colored "sour" mud around the gas escapement, which has no resemblance whatever to paraffin dirt. Typical occurrences of this class include the well known original gas escapements at Markham and Anse-la Butte. While the writer never saw the hole at Spindletop through which hydrogen sulphide gas escaped before the pool was developed, it is his opinion, from descriptions, that this probably corresponded quite closely to the two above-mentioned localities.

Apparently the most favorable locality for the formation of paraffin dirt beds is a damp, seepy spot, over or around which vegetation flourishes, though the spot need not necessarily be marshy. It is quite as often true that the deposits are found on the open prairie as in timbered regions.

The range over which paraffin dirt has been found by the writer lies in the Gulf Coastal Plain, bounded on the West by the Colorado River,

the boundary swinging northward north of Humble and including east Texas as far north as Shreveport. The dirt is quite common in western and southern Louisiana, but none has been seen in northeastern Louisiana, Arkansas or Mississippi, although the climate and vegetation in these localities does not seem to differ in any important particulars from those in east Texas and Louisiana. There seems to be no good reason for its absence in parts of northern Louisiana, and it may very likely have been found there by others more familiar with this section. Geologists who are familiar with conditions in Cuba, think they have identified the dirt there also.

It will be observed that the territory over which paraffin dirt is common lies in the region of 40 in. or more of annual rainfall, and is so situated geographically as to permit of only slight differences in conditions of vegetation. In other words, over this section, conditions are such as might well permit the formation of peat deposits. It will also be noted, however, that paraffin dirt is found over only such portions of this territory as afford known gas seepages. It seems more than likely that if climatic conditions were suitable to support a satisfactory mantle of vegetation, with attendant conditions of moisture, paraffin dirt might well be expected to accompany gas seepages in sections where it does not occur.

Returning to the question of the character of the gas accompanying deposits of this material, it has been the writer's observation that sulphur gas was nearly always present. Hydrogen sulphide gas is quite commonly, if not universally, present where oil is found associated with salt domes. In Shelby and Sabine Counties, Texas, and in Sabine Parish, La., paraffin dirt is quite abundant, particularly along Flat Fork and Sabine River, near old Sabinetown. Near Negreet, La., a short distance east of Sabinetown, the gas seepages are decidedly sulphurous. The gas near Negreet burns with a pale blue, almost invisible flame, and in crevices and joints in the clays, crystalline sulphur is found. This region, however, belongs more properly in a geologic sense to the Sabine Uplift than to the Coastal Plain, and the deep gas associated with the Sabine Uplift is "sweet" gas quite free from sulphur. It may therefore be true that the seepages of sulphur gas are not emanations from the deep gas sands, but have their origin in the sediments above the oil and gas horizons. The territory in and around the Caddo field is surely an ideal place to expect paraffin dirt beds, unless they are in some way dependent on the presence of sulphurous gases, but the writer has never personally encountered them there.

In Terrebonne and adjoining parishes of Louisiana, gas escapements and paraffin dirt are so abundant as to create a suspicion that not all the gas is petroleum gas. Deep drilling has demonstrated the presence of an abundance of deeply buried vegetation, notably tree trunks, some

partially carbonized, others partly decomposed to a pithy texture of the lightness of cork. In fact, if this proof of buried organic matter were not at hand, one might safely assume its presence, owing to the semi-alluvial character of the sediments in that region. It is the writer's belief that more or less of the surface gas is derived from this source. It is no doubt true also that a part of it comes from deep gas or oil sands. Evidence of this fact is found in the discovery of gas in the Knapp and Gulf Refining Co. wells near Montegut, below 1600 ft., and in the McCormick well 15 miles southeast of Houma, at over 2700 ft. In none of these wells is salt-dome structure indicated, and we must assume that if a salt dome is present, these wells are considerably offside, or else the salt core is so deeply buried as to be beyond the reach of the drill. If oil is found in this region, it would naturally be expected around salt domes. This section lies in a portion of the Mississippi Embayment where recent sediments are undoubtedly very thick, and it is likely that if salt cores are present, they are very deeply buried.

The writer is prone to accept Mr. Brokaw's suggestion that the peculiarities of paraffin dirt are due to unoxidized peaty material which has been deposited in a gas-saturated soil, since it fits in with all the conditions enumerated above. He is inclined to believe, however, that the gas saturating the soil must necessarily be a sulphurous gas, but is open to conviction on this phase of the subject. He believes also that this material, once formed, is not subject to ready oxidation or decay, as paraffin dirt is occasionally found where it appears that the gas escapement has ceased.

The idea of the vegetable or peaty character of paraffin dirt is not altogether new. Dr. J. A. Udden, in a personal communication dated March 13, 1913, with reference to specimens sent him by the writer from localities in Louisiana, said: "I find that most of it will burn, leaving about 30 per cent. ash. Only a minor part of this ash appears to be of mineral origin, such as sand. I find that it is nearly all soluble in potassium hydrate. Its elasticity and other physical qualities make me believe that it is identical with the mineral which has been described as "dopplerte," in Germany; or the related mineral known as "phytocollite." This mineral is supposed to be a precipitation of vegetable matter which has combined with soda or potassium, or some other base. The precipitation has taken place in such waters as those known as "black waters," containing much humic material in solution."

To what extent, then, may paraffin dirt be relied upon as an indication of oil? The writer's attention was first attracted during 1909 to the probable association of this substance with oil and gas at the above-mentioned locality near Negreet. His associates, Messrs. L. P. Garrett and B. S. Sorelle of Beaumont, were also of the opinion that paraffin earth was a valuable surface indication and in our subsequent joint investiga-

tion of probable oil prospects, particular attention was paid to this substance. Reëxamination of certain localities proved that paraffin dirt was present where we had previously failed to find it, but had later concluded conditions were such that it should have been found. In looking over some of the gas seepages around several of the developed pools which had been relied upon in the early prospecting, paraffin dirt was discovered, notably on the Slaughter tract at Humble, and at Goose Creek. Although we were sometimes unable to find it, we concluded that it had no doubt been present at Sour Lake, Jennings, Anse la Butte, and elsewhere, but that all traces of it had been obliterated around the older pools, before our investigation, by the incessant and intensive changes incident to oil-field development when confined to such small areas. Instances where it was relied upon in advance of the discovery of oil include Edgerly, La., Cow Bayou, Orange County, Tex., and the New Iberia, La., pool. Instances where its presence is known but where prospecting has not yet proved the presence of oil are numerous and well known, and need not be enumerated here.

The writer's opinion is that this substance almost invariably indicates the presence of a gas seepage, and probably one in which sulphur gas is present. These seepages along the Gulf Coastal Plain are quite likely to be of deep-seated origin, the gas under high pressure having found its way to the surface along the face of the salt core or through the numerous intercommunicating water sands. But it may also, where climatic conditions are suitable, indicate gas seepages which are not associated with oil. It may therefore be classed as one of the most important indications of oil along the Gulf Coastal Plain, inasmuch as the gas which causes its deposition is quite apt to originate in an oil pool. It would perhaps be a better statement of the case to say that in this region paraffin dirt more than likely indicates the presence of a submerged salt core. This statement may be premature, however, since recent investigation, particularly in southern Louisiana, has brought to light a large number of new deposits which have not as yet been drilled. One is loath to admit the possibility of the existence of such a large number of new salt domes, as seem thus to be indicated, until further drilling has been done.

E. G. WOODRUFF,* Tulsa, Okla. (written discussion†).—In this paper on paraffin dirt, Dr. Brokaw has given us valuable data on a subject which is of both scientific and financial interest to the Gulf Coast oil operators. It is regrettable that he has been forced to confine his attention to a laboratory examination of the earth, rather than to include a field study also. My own experiences have been limited to field observations supplemented by reports from chemists. These

* Chief Geol., Sperry Oil & Gas Co.

† Received June 4, 1918.

chemists find no paraffin in the "earth." It is called paraffin earth by the field scouts because, as described by Dr. Brokaw, it looks like paraffin-impregnated clay.

Some of the Gulf Coast operators think that the presence of the paraffin earth is associated with oil fields. This supposition is perfectly rational since in most, if not all, of the low clay-coated oil fields, this peculiar spongy earth is found on the surface. It is not found where the surface strata are sand or very sandy clay. As far as I am aware, it is found only where there are gas escapes. I had an opportunity to study this earth, especially in Terrebonne Parish, La., where there are gas wells of immense capacity. Here the surface is flat and swampy, and both the gas escapes and the paraffin earth are common.

A paraffin earth locality may embrace a considerable area, possibly one hundred acres, with the paraffin earth spotted over the area; each spot irregular in shape and covering a few square feet or yards. The ground is largely a clay soil carrying a large percentage of vegetable matter, and is saturated with water, or at least very moist.

Where soil cracks occur, the pure paraffin earth occurs as an incrustation along the walls of the cracks. When a small soil block from two to four inches across, for example, is examined, it is found that this coating quickly merges into an intermixture of paraffin earth and native soil which grades into unaltered soil in the interior of the soil blocks. Stated another way, there seems to be a coating of paraffin earth on the sides of the blocks of soil behind which there is a partial alteration of the soil, while in the interior of the blocks there is no alteration.

In the field it appears as if gas escaping along weather cracks in a moist humus soil has altered the soil to a rubbery clay. I am inclined to think that most commonly this gas is marsh gas produced by the alteration of the vegetation, probably near the surface. In some places, it may be that petroleum gas has produced the effect, but no doubt this is rare. I believe, therefore, that the presence of paraffin earth does not necessarily indicate an oil or gas reservoir of commercial importance.

The process by which this earth is produced can only be suggested. It may be due to a sort of plucking action of gas-agitated water on the clay soil, or it may be due to chemical action. I am inclined to think it is the latter.

In private correspondence, Prof. Heinrich Ries speaks of the paraffin earth as a hydrous aluminum silicate and mentions its occurrence at various places in the Southern States.

INDUSTRIAL SECTION

This department is devoted to material concerning the products or operations of manufacturers, which, in the estimation of the Editor, is of news value to the mining and metallurgical field, but does not come within the scope of the main editorial section of the Bulletin.

Manufacturers are invited to submit to the Editor items descriptive of new equipment or processes, large or significant installations, and similar material of news character. If found available, items thus furnished will be published in this section without charge, subject to such editorial revision and condensation as may be necessary.

In cases where illustrations are required, cuts of the proper size should accompany the text matter.

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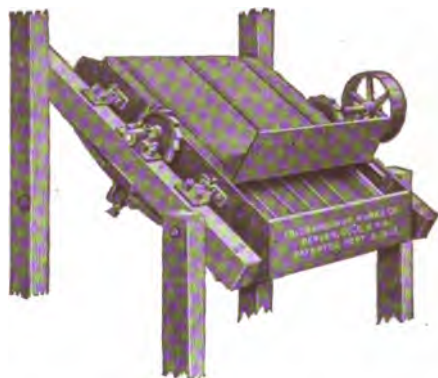
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No. 140

AUGUST

1918

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COLORADO MEETING, SEPTEMBER 1 to 7, 1918

COMMITTEE IN CHARGE

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L. B. EAMES
F. ROBINSON

PROGRAM FOR COLORADO MEETING

The program for the Colorado Meeting, as announced by the committees in charge, stands as follows:

SUNDAY, SEPT. 1

Registration and temporary headquarters in the Brown Palace Hotel, Denver.

MONDAY, SEPT. 2

- 9 a. m. Technical session on Metallurgy.
- 11 a. m. Automobile trip to the ferro-alloy plant and other points of interest in the city of Denver, followed by the mountain trip.
- 1 p. m. Luncheon at the Hosea Lodge in Genneessee Park, on Lookout Mountain.
- 4.30 p. m. Technical session on Coal and Coke.
- 7.00 p. m. Dinner at the Country Club in Denver.

TUESDAY, SEPT. 3

- 8.15 a. m. Take train from Denver to Colorado Springs, arriving at 11 a. m. Permanent registration headquarters will be established in the Broadmoor Hotel. Technical session, if convenient.
- 1.00 p. m. Luncheon at the Broadmoor Hotel.
- 2.00 p. m. Technical session.
- 8.30 p. m. Reception and dance.

WEDNESDAY, SEPT. 4

All-day trip to Cripple Creek, followed by a technical session in the evening if considered desirable.

THURSDAY, SEPT. 5

- 8.00 a. m. Automobile trip to Pike's Peak.
 - 2.00 p. m. Visit to the Golden Cycle mill.
- Technical sessions will be arranged for afternoon and evening as desired.

FRIDAY, SEPT. 6

- 8.30 a. m. Take train for Pueblo.
- 12.30 Luncheon at the Minnequa Steel Works, at Pueblo.
- 4.00 p. m. Technical sessions, after which the party will return to Colorado Springs.
- 7.30 p. m. Banquet at the Broadmoor Hotel.

The proposed trip to Leadville will probably have to be abandoned on account of the suspension of operation by the Colorado-Midland Railway. An optional trip will be arranged if considered desirable.

The Committee in charge promises an attractive program for the entertainment of ladies.

U.S. Geol. Survey

TECHNICAL SESSIONS

Session on Metallurgy

Oxygen and Sulphur in the Melting of Copper Cathodes. By S. Skowronski. (Bulletin No. 135, p. 645.)

The Relation of Sulphur to the Overpoling of Copper. By S. Skowronski. (Bulletin No. 135, p. 651); with discussion by Philip L. Gill. (This Bulletin.)

Electrolytic Zinc. By C. A. Hansen. (Bulletin No. 135, p. 615.)

The Practice of Antimony Smelting in China. By C. Y. Wang. (Bulletin No. 136, p. 927.)

The Metallography of Tungsten. By Zay Jeffries. (Bulletin No. 138, p. 1037.)

The Condensation of Zinc from Its Vapor. By C. H. Fulton. (This Bulletin.)

The Manufacture of Ferro-alloys in the Electric Furnace. By R. M. Keeney. (This Bulletin.)

Electrostatic Precipitation. By O. H. Eschholz. (This Bulletin.)

Session on Coal and Coke

The Byproduct Coke Oven and Its Products. By W. H. Blauvelt. (Bulletin No. 135, p. 597.)

The Use of Coal in Pulverized Form. By H. R. Collins. (Bulletin No. 136, p. 955.)

Coal Mining in Washington. By F. A. Hill. (Bulletin No. 136, p. 951.)

Carbocoal. By C. T. Malcolmson. (Bulletin No. 137, p. 971.)

Development of the Coke Industry in Colorado, Utah and New Mexico. By F. C. Miller. (This Bulletin.)

Session on Ore-dressing and Cyanidation

Hand-sorting of Mill Feed. By R. S. Handy; with discussion by A. Stanley Hill, W. L. Ziegler, L. O. Howard, Clarence A. Wright, D. C. Bard, S. A. Easton, F. A. Thomson, W. H. Linney, and the author. (Bulletin No. 136, p. 913.)

The Automatic Separation of Solution from Solids in the Hydro-metallurgical Treatment of Ore Pulps. By Bernard MacDonald. (Bulletin No. 139, p. 1141.)

Fine-grinding Cyanide Plant of Barnes-King Development Co. By J. H. McCormick. (This Bulletin.)

The Effect of Oxygen upon the Precipitation of Metals from Cyanide Solutions. By T. B. Crowe. (This Bulletin.)

Roasting for Amalgamating and Cyaniding Cripple Creek Sulphotelluride Gold Ores. By A. L. Blomfield and M. J. Trott. (This Bulletin.)

The Tailing Excavator at the Plant of the New Cornelia Copper Co., Ajo, Ariz. By Frank Moeller. (This Bulletin.)

The Elko Prince Mine and Mill. By J. V. N. Dorr and L. D. Dougan. (This Bulletin.)

Crushing Resistance of Various Ores. By Luther W. Lennox. (This Bulletin.)

Session on Economic Geology and Mining Practice

The Relation of Sulphides to Water Level in Mexico. By P. K. Lucke. (Bulletin No. 138, p. 1105.)

The Mechanics of Vein Formation. By Stephen Taber. (This Bulletin.)

Pyrite Deposits of Leadville, Colorado. By Howard S. Lee. (This Bulletin.)

Molybdenite Operations at Climax, Colorado. By D. F. Haley. (This Bulletin.)

Radium. By Richard B. Moore. (This Bulletin.)

Fireproofing Mine Shafts of the Anaconda Copper Mining Co. By E. M. Norris. (Bulletin No. 135, p. 657.)

Air Blasts in the Kolar Gold Field, India. By E. S. Moore. (Bulletin No. 135, p. 687.)

Engineering Problems Encountered During Recent Mine Fire at Utah-Apex Mine, Bingham Canyon, Utah. By V. S. Rood and J. A. Norden. (Bulletin No. 138, p. 1093.)

Man Power. By J. Parke Channing. (Bulletin No. 137, p. 963.)

Session on Petroleum

Gaging and Storage of Oil in the Mid-Continent Field. By O. U. Bradley. (Bulletin No. 135, p. 677.)

An Interpretation of the So-called Paraffin Dirt of the Gulf Coast Oil Fields. By A. D. Brokaw. (Bulletin No. 136, p. 947); with discussion by W. E. Wrather and E. G. Woodruff (Bulletin No. 139, p. 1148) and Lee Hager (This Bulletin.)

The Theory of Volcanic Origin of Salt Domes. By E. L. DeGolyer. (Bulletin No. 137, p. 987); with discussion by J. A. Udden. (Bulletin No. 139, p. 1147.)

A Concrete Example of the Use of Well Logs. By Mowry Bates. (Bulletin No. 137, p. 979.)

Oil in Southern Tamaulipas, Mexico. By Ezequiel Ordoñez. (Bulletin No. 137, p. 1001.)

Geology of the Oil Fields of North Central Texas. By Dorsey Hager. (Bulletin No. 138, p. 1109); discussed by Wallace E. Pratt. (This Bulletin.)

Losses of Crude Oil in Steel and Earthen Storage. By O. U. Bradley. (Bulletin No. 139, p. 1135.)

The Possible Existence of Deep-seated Oil Deposits on the Gulf Coast. By A. F. Lucas. (Bulletin No. 139, p. 1119.)

Staggering Locations for Oil Wells. By R. H. Johnson. (This Bulletin.)

Lithology of the Berea Sand in Southern Ohio, and Its Effect on Production. By L. S. Panyity. (This Bulletin.)

MILWAUKEE MEETING, OCTOBER 8-11, 1918

A joint meeting of the American Institute of Metals Division, and the iron and steel members of the American Institute of Mining Engineers, with the American Foundrymen's Association, has been arranged for Milwaukee, beginning on Tuesday, October 8, 1918. The papers to

be presented by the Institute of Metals Division are given below; those under the auspices of the Committee on Iron and Steel, Joseph W. Richards, Chairman, will deal with iron ores, iron and steel metallurgy, and related subjects.

Programs for the meetings, as provisionally arranged, are as follows; they will be given in fuller detail in the September Bulletin.

AMERICAN INSTITUTE OF METALS DIVISION

Tuesday morning, October 8:

The Metallography of Tungsten, by Zay Jeffries. (See A.I.M.E. Bull. No. 138, p. 1037.)

The Constitution of the Tin Bronzes, by S. L. Hoyt.

Paper, title not given, by C. H. Mathewson.

Wednesday morning, October 9:

Symposium on the conservation of tin. Those taking part will be the following:

Dr. G. W. Thompson, of National Lead Co.,

Mr. G. H. Clamer, of the Ajax Metal Co.,

Mr. C. M. Waring, Pennsylvania Railroad Co.,

Mr. M. L. Lissberger, of Mark Lissberger & Son, Inc.,

Mr. D. M. Buck, American Sheet & Tin Plate Co.,

Mr. W. M. Corse,

Messrs. Burgess and Woodward, U. S. Bureau of Standards,

Mr. M. L. Dizer, of War Industries Board.

A representative of the Niles-Bement-Pond Co.,

A representative of the Bureau of Steam Engineering, U. S. Navy Dept.

Wednesday afternoon, October 9:

The Volatility of the Constituents of Brass, by John Johnston.
(See *Journal*, Am. Inst. Metals, March, 1918, p. 15.)

Notes on the Metallography of Aluminum, by P. D. Merica and J. R. Freeman, Jr.

The Effect of Impurities on the Hardness of Cast Zinc or Spelter, by G. C. Stone. (See *Journal*, Am. Inst. Metals, March, 1918, p. 11.)

Dental Alloys, by Dr. Arthur W. Gray.

Thursday morning, October 10:

Notes on Non-metallic Inclusions in Bronzes and Brasses, by G. F. Comstock. (See *Journal*, Am. Inst. Metals, March, 1918, p. 5.)

Nichrome Castings, by Mr. Arlington Benzol, of Driver-Harris Wire Co.

Fusible Plug Manufacture, by Messrs. G. K. Burgess and L. J. Gurevich.

Paper, title not stated, by P. D. McKinney.

Application of the Spectroscope to the Chemical Determination of Lead in Copper, by Messrs. Hill and Lucke.

AUSPICES OF IRON AND STEEL COMMITTEE

The sessions on Iron and Steel will be held on the morning and afternoon of Wednesday, October 9. In addition to a number of papers on iron ore, ferro-alloys, etc., interesting lectures, to be illustrated by moving pictures, will probably be given on the manufacture of steel, and on the training and employment of cripples for industrial occupations. A full program will be printed in the September Bulletin.

NEW YORK MEETING, FEBRUARY 17-20, 1919

In preparation for the 118th meeting, New York, Feb. 17 to 20, 1919, the following committees have been appointed:

Committee on Arrangements

ALLEN H. ROGERS, *Chairman*.
J. E. JOHNSON, JR.
H. C. PARMELEE.

W. S. DICKSON, *Secretary*.
F. T. RUBIDGE.
FOREST RUTHERFORD.
P. G. SPILSBURY.

Committee on Annual Dinner

F. T. RUBIDGE
E. B. STURGIS.

Committee on Luncheon

FOREST RUTHERFORD, *Chairman*.
E. MALTBY SHIPP.

Committee on Patriotic Meeting

H. C. PARMELEE, *Chairman*

MEETING OF THE BOARD OF DIRECTORS, JUNE 21, 1918

A meeting of the Board of Directors was held in the Council Room of the U. S. Bureau of Mines, Interior Building, Washington, D. C., on Friday, June 21, 1918, at 4 p. m.

Twelve members of the Board, the Secretary of the Institute, and nine guests were present.

Upon the petition of 28 members of the Institute residing in or near Washington, D. C., a Washington Section was authorized. A committee was appointed to nominate officers and prepare a set of by-laws.

The report of the Treasurer was presented in writing, accepted, and ordered filed.

Thirty-nine members, 12 associates and 8 junior associates were elected. Two members were reinstated. One resignation was accepted. The dues of 64 members were suspended on account of their being on active war duty.

LOCAL SECTION NEWS

NEW YORK SECTION

ALLEN H. ROGERS, *Chairman*, H. C. PARMELEE, *Vice-chairman*,
FOREST RUTHERFORD, *Vice-chairman*,
W. S. DICKSON, *Secretary*, 71 Broadway, New York, N. Y.
J. E. JOHNSON, JR. F. T. RUBIDGE, *Treasurer*, P. G. SPILSBURY.

The annual meeting of the New York Section, for the election of officers and other business, was held at the Machinery Club on May 23.

1918. It was preceded by a dinner which was attended by about 50 members, others arriving in time for the meeting.

The by-laws of the Section were changed so as to provide for the election of an executive committee consisting of a Chairman, two Vice-chairmen, a Treasurer, and two more members, the Secretary to be selected by the other members of the committee. The result of the election of officers is shown above.

The Treasurer's report was read and placed on file.

The subject for the evening was "Iron Resources of the World in Relation to National Economic Conditions after the War." The following gentlemen spoke on various phases of this topic: E. C. Harder, Waldemar Lindgren, C. M. Weld, A. C. Spencer, H. Foster Bain, and Sidney Paige.

A. D. BEERS, *Secretary*.

(The discussion elicited at this meeting is considered of such importance as to warrant its publication as a paper in the *Bulletin* for September, in time for presentation at the special iron and steel session of the Institute, at Milwaukee, Oct. 8-10, 1918.—Ed.)

SAN FRANCISCO SECTION

A. C. LAWSON, *Chairman*,

ROY H. ELLIOTT, *Vice-chairman*,

W. H. SHOCKLEY, *Sec'y-Treas.*, 959 Waverly Street, Palo Alto, Cal.

T. A. RICKARD,

C. F. TOLMAN, JR.

Meeting of May 7, 1918

The meeting of May 7, 1918, was held at the Engineer's Club; 25 members and guests were present. The paper of the evening, "The Geology, Mineral Associations and Origin of California Ores," was given by Professor C. F. Tolman, Jr., of Leland Stanford Junior University, the substance of whose remarks was as follows:

Professor Tolman referred to the excellent paper of S. F. Emmons, "Theories of Ore Deposition Historically Considered" (Bull. Ind. Sec. Am., Vol. 15, 1904, pp. 1-28), wherein the earliest theories of ore deposition were reviewed. The ancients seem to have been without curiosity as to rocks or ores, and had no theories. It is indeed remarkable that such acute observers as the Chinese and the Greeks saw so little in the rocks; apparently they had no conception of the nature of fossils or even of the origin of sandstone. One of the earliest speculators on the subject was Descartes, the founder of modern philosophy, who, in 1664, called the earth a dead sun with a hot center, and ascribed the formation of ores to the heated waters which, infiltrating from above, were heated and driven back to the surface and deposited the ores during their return journey. In 1668, Steno, a Dane, considered that ores were formed by the action of emanations from volcanoes. Thus at the very outset the two theories were stated that have lived to the present day.

It was soon discovered that ores were not deposited exclusively as fissure fillings, and by 1768 Zimmermann undertook to explain the phenomena of replacement; later, von Treba, a mine superintendent, explained clearly that replacement of rock by ore-minerals took place molecule by molecule. Among these early theorists there was much confusion because of the lack of the knowledge of chemistry, and after the division of geologists into the two schools of Neptunists and Plutonists the wordy wars became most violent. The Plutonists swore by the

ascending solutions, while the Neptunists found all ores were formed by descending solutions.

In 1846, Elie de Beaumont described hot spring action, ascribing to the water, in part, a magmatic origin. Still more important was his recognition that vapors and gases were given off by volcanoes, such as boron, fluorine, chlorine, hydrogen sulfid, carbon dioxide, etc. He and his illustrious successors in France believe that the crystallization of igneous rock is under the control of mineralizers. These mineralizers are concentrated during the gradual crystallization of the rock and find expression in a series of "after effects" such as pegmatite dikes, contact action, high-temperature veins—and later veins of intermediate temperature. Elie de Beaumont showed that tin oxide might be formed by the action of hot vapors containing fluorine—that fluorine forms the volatile tin fluoride, which upon escape of hydrofluoric acid and reaction with water forms tin oxide; he also showed that the alteration of the country rock and the formation of topaz, tourmaline, fluorite and the other minerals that accompany tin veins could likewise be accounted for by the escaping vapors.

One of the most important concepts in the theories of ore deposition is that which gives importance to the presence of water in the molten rocks. The German theorists have led us astray by considering molten rock as dry. And it is only within the last few years that the importance of mineralizers has been recognized. Even in regard to the so-called magmatic ores, the microscopic investigations of Professors Tolman and Rogers have disproved the old theory that in the cooling molten mass the heavy metals settle out first. The sulfids and oxides are later in origin than the silicates and, in part, replace the latter and are undoubtedly segregated by the action of mineralizers.

The long-continued dispute between the ascensionists and descensionists received impetus from the work of Sandberger, who assayed the country rock of mineral districts and found traces of metals in the wall rock. Sandberger did not realize that the metallic content of the altered rock was introduced by solutions escaping from the veins.

Since Sandberger's work in 1880, the application of scientific methods of investigation has been accumulating facts that promise to substitute for mere speculation the true story of the origin of ores. Geological study has given us information as to the depth at which certain ores are formed; has located the episodes of ore formation in the geological history of the region. Summarizing these data, De Launay has shown that ores are not formed at any old time, but there are world-wide metallogenetic epochs. One of these active periods, the "Hercyman," occurred at the close of the Carboniferous period. Ore deposition was slight in the United States but the tin veins of Europe, which occur on the margin of the granitic rocks and were formed at high temperatures, and the tin deposits of the Malay States and eastern Australia, and the important gold deposits of eastern Australia, were formed at this time.

The broad studies of the U. S. Geological Survey, supplemented by the chemical work of the Geophysical Laboratory at Washington, enable us to tell whether minerals have been deposited near the surface or in depth, and at what temperatures, so that, given the group of minerals making up an ore deposit, we know something as to the depth and temperature of its formation, and also whether the ores were formed by hypogene (primary) or supergene (secondary) processes. We are collecting data

in regard to the range of minerals; some are formed under varying conditions, while others are "critical." Chalcopyrite is formed in depth and at high temperatures, and also by descending solutions, which, in Alaska, must have been at nearly freezing temperature. Pyrrhotite, on the other hand, is a high-temperature mineral with a limited range of formation.

The study of polished mineral surfaces under high magnification is determining the order of deposition of the ore minerals, and is proving that the earlier minerals are deposited at the higher temperature and that the later minerals were introduced in general at lower temperatures.

Professor Tolman summarized briefly the geological history of California and showed that great mineral activity followed the intrusion of the great Sierra Nevada batholith, consisting of diorites, greenstones, and gabbros. Taking his conclusion that certain geographical areas may be considered as units in regard to their geological history, and that metallization has occurred as definite episodes in the geological history, he defined certain mineral districts, the deposits of which show similarities in character and origin. The character of the ores of the various districts was illustrated by a large number of lantern slides, most of them of polished ore specimens highly magnified, one, in fact, being magnified 36,000 diameters. These specimens were from many portions of California and were described in connection with his discussion of the ore deposits.

Among the districts that were described were the following: the Coast Range copper deposits; the copper deposits of Siskiyou County; the copper deposits of Shasta County; the copper-lead-zinc deposits of South-eastern California; the copper and nickel deposits of San Diego County; the gold deposits of the Sierra Nevada; and the Foothill copper belt.

Professor Tolman summarized the data available from the geology of the deposits and of the mineral regions in which they occur, and more especially described the mineral relations as brought out by microscopic study. These relations were beautifully illustrated by lantern slides.

His conclusions in regard to the mineral regions discussed are briefly as follows: The scattered copper deposits of the Coast Ranges are of various types, and differ in origin. The notion that they are merely superficial concentrations is not verified by microscopic work. The lenses of chalcocite in serpentine are derived from original bornite, and are probably in part of magmatic origin. All these copper deposits, which are not in general of economic importance, appear to have a genetic relation to intrusive serpentine.

The Siskiyou copper deposits are interesting because they are chiefly high-temperature deposits, consisting of pyrrhotite-magnetite-arsenopyrite, chalcopyrite, bornite, and marcasite. Marcasite is later than the other iron sulfids and may have been formed by descending solution. Although pyrrhotite is the most abundant sulfid, and has been considered very "active" in precipitating "secondary sulfids," almost no downward enrichment was noted, and the small amount of supergene chalcocite and covellite present was formed at the expense of original chalcopyrite and not precipitated by pyrrhotite. The high-temperature character suggests a relation to the numerous intrusive masses that are apophyses of the Sierra Nevada batholith. Geological knowledge is lacking and this hypothesis cannot be proved or disproved without further geological data.

In regard to Shasta County copper deposits, attention was called to

Mr. Graton's work, and his conclusions that these deposits were genetically related to an intrusive body of "alaskite porphyry." The latter is probably an outlier or apophysis of the Sierra Nevada batholith. The mineralogy of these deposits was discussed briefly and the similarity of these copper-lead-zinc deposits, with only subordinate supergene enrichment, to the deposits of the Foothill Copper belt was pointed out.

The general geological relations of the "contact family" of deposits in southeastern California were discussed. Their similarity to the "Arizona type" of deposits formed in the vicinity of small intrusive bodies of acid or intermediate composition was brought out.

The copper and nickel deposits of San Diego County were mentioned briefly. They belong to the type of magmatic copper-nickel deposits discussed in detail by Professors Tolman and Rogers recently. In San Diego, the gabbro which contains the orebodies is one of the suite of basic rocks that represent the earlier intrusive phases of the Sierra Nevada batholith.

Perhaps the most interesting portion of the discussion was that which related to the origin of the gold and copper deposits of the Sierra Nevada. It was shown that there was a "regional variation" in the mineralogy of both the gold deposits and the Foothill copper belt, and that the mineral composition depends upon the distance of the deposits from the Sierra Nevada batholith and its apophyses.

The highest-temperature deposits are represented by the veins at Meadow Lake, pyrite-gold-tourmaline-epidote veins situated within the granite of the batholith. Few would deny that these veins are formed from the direct high-temperature extract of the granitic magma.

Next in temperature come the "East Lode" veins which lie along the granite contact, and in part in the granite. These include the well-known Black Oak mine, the Defender, Volcano, and Sheep Rancho mines, and many others, in Tuolumne, Calaveras, and Amador Counties. These mines are characterized by the abundance of sulfids, viz., pyrrhotite, arsenopyrite, pyrite, sphalerite, chalcopyrite, and galena. Pyrrhotite, arsenopyrite, and also magnetite, and occasional molybdenite, show conclusively a rather high-temperature origin. Diorite dikes have been reported cutting the veins of the East Lode, and as these dikes undoubtedly are members of the intrusive suite that makes up the batholith, the east lode deposits fall under the period of control by igneous processes.

The great Mother Lode shows mineral associations suggesting intermediate temperature of formation, but the southeastern continuation along the contact between the metamorphics and the great mass of granite develops contact deposits with garnet, epidote, and gold-quartz intermixed. Hence, temperature of deposition increases from the center of the central portion of the northern lode southeasterly toward the granite. A similar but less pronounced increase in temperature northwesterly from the center of the Mother Lode was shown. In this direction small fingers or offshoots of the main batholith become abundant.

A similar change in the mineral composition of the Foothill copper belt is noted, corresponding to the distance from the batholith. The belt centers in Calaveras County; northeastward, in El Dorado County, mineralization extends up to the main granodiorite contact and along minor intrusive masses, and typical high-temperature, contact deposits

are found. Southeasterly, as the belt enters the zone of metamorphic rock caught up in the main mass of the granite, pyrrhotite and magnetite take the place of pyrite, and the interesting copper iron mineral, chalmersite, comes in, which, in association with chalcOPYrite, accounts for the copper content of the ores.

Curiously, just like the pyrrhotite deposits of Siskiyou County, the pyrrhotitic deposits of the southeastern portion of the Foothill copper belt have undergone only subordinate sulfid enrichment, but locally considerable oxide enrichment.

Summarizing then, the important gold and copper deposits were formed immediately after the epoch of great igneous activity that marked the intrusion of the Sierra Nevada batholith and are genetically related to this activity.

Professor Lawson spoke of the vastness of the subject and the impossibility of discussing it at any length because of the lateness of the hour. A point that had struck him was the great similarity between these polished ore-slides and the slides of the alloys made by metallographers; many of the phenomena shown are identical. Hence the arguments drawn as to the succession of minerals during a long cooling period seem to fall, because the alloys cool instantly and there is no long interval of time. Some comparative study should be made of these alloys and minerals. Therefore some of Professor Tolman's conclusions seem doubtful, although the facts disclosed in the photographs are indisputable. Moreover, diametrically opposite conclusions may be drawn from the same slide by competent observers.

In reply to Professor Lawson's criticism, Professor Tolman stated that he has investigated the structure of alloys and felt sure his interpretation of the ore-slides was correct. Some structures are similar, but the replacement structure is never seen in alloys. Professor E. A. Hersam remarked that while many of the phenomena shown by minerals are reproduced by alloys, yet there are also many differences, and in nature variable conditions are found that do not exist in metallurgy.

SOUTHERN CALIFORNIA SECTION

RALPH ARNOLD, *Chairman*, WILLIAM F. STAUNTON, *Vice-chairman*,
ALVIN B. CARPENTER, *Sec'y-Treas.*, 530 Citizens National Bank Bldg., Los Angeles, Cal.
A. B. W. HODGES, C. COLCOCK JONES, LESLIE C. MOTT, JAMES W. NEILL.

At a meeting of our Executive Committee a short time since, it was decided to attempt an innovation in our accepted routine, and while the usual form of meeting of the Section would be held during the coming year, it was proposed that we institute a series of informal affairs at the residences of some of the members. It was hoped that not only would such meetings aid in the better acquaintanceship of the members of the Section, but also that the informality of these meetings would tend to make the subjects to be considered more generally discussed.

The initial try-out of this idea occurred at the residence of the Secretary on the evening of June 5, and as a result of the experiment, we learned a great many things.

The subjects presented were not read, but talked, and copious data were available for reference. Maps and diagrams were spread out on a rug on the floor. The speakers talked from their chairs without rising, and the company was seated in a circle two rows deep, with the maps in the

center. There were 21 members present. The subject presented was "Fuel and Power Problems in the West under War Conditions." Three important phases of the subject were considered, as follows:

The Oil Situation, by Mr. Robert Moran.

Coal and Coke in the West, by Mr. C. Colcock Jones.

Hydro-electric Possibilities, by Mr. H. A. Barre, one of the prominent electrical engineers of Los Angeles.

Never in the history of the meetings of this Section has there been so general a discussion. Practically everyone had something to say or questions to ask. A discussion of the coal and coke on the West Coast, a subject but little known in a general way, developed particular interest from the personal experiences of no less than five members present. The subjects of oil and hydro-electric power and their present relationship, the possibilities for the future and the trend and progress toward the coming electrical age for this section of the country, made the general subject a constructive one of great interest.

A half hour of sociability and a near-midnight luncheon concluded a very successful and enjoyable evening.

ALVIN B. CARPENTER, *Secretary*.

WASHINGTON SECTION

HERBERT C. HOOVER, *Chairman*,

H. FOSTER BAIN, *Vice-chairman*,

DAVID WHITE, *Vice-chairman*,

HARVEY S. MUDD, *Sec'y-Treas.*, Room 2114, Dept. of Interior Bldg.,

J. F. CALLEREATH,

HENNEN JENNINGS,

E. W. PARKER,

T. T. READ.

On the evening of June 21, 1918, the Washington members gave a dinner, in the Food Administration Building, to the President and Board of Directors of the Institute. At the close of this meeting, the formal organization of the Washington Section was announced, with officers as listed above; this assembly is therefore here recorded as the first meeting of the Washington Section.

The meeting was called to order by Van H. Manning, Director of the Geological Survey; after a courteous acknowledgment of the kindness of the ladies present, members of the Food Administration staff, who had volunteered as waitresses for the occasion, he introduced, as toastmaster, F. S. Peabody, who is in charge of the explosives regulations of the Department of the Interior.

F. S. PEABODY.—I will propose a toast which I think should always be proposed first in any public gathering. No one, acting as spokesman at any public gathering, should fail to speak of that wonderful man who is carrying the burdens of our country on his shoulders, who listens not to carping critics, whose head is unbowed before hostile criticism, who is undaunted by mistakes of his subordinates, that are sure to come, but who stands with body and head erect, with clear vision and prophetic words, and so wonderfully and fearlessly expresses the deepest and purest thoughts of our soul in this, the most trying period in which civilization has ever been tested by the fire of self-sacrifice; a man whom every man, woman and child, not only in this country, but in every right and free-thinking country in the world, should support. I mean our President. God bless and help him to lead us to a glorious victory of right over wrong, of freedom over serfdom, of civilization over kultur. (Applause.)

Miss Van Rensselaer, one of Mr. Hoover's chief assistants, and the young ladies who have been good enough to serve us tonight—I don't

believe we realize how good they are and what an example they set to the world. Mr. Hoover tells me Miss Van Rensselaer is in charge of so much that he cannot tell me in a few words just what her work does include. He tells me that she has 700,000 women working under her in this country. I wonder, Miss Van Rensselaer, would it be imposing upon you if we asked you to say a word to us about your work?

MISS VAN RENSSELAER.—Gentlemen, I know of nothing better in life than to be able to be with men. Perhaps there is one thing better, but I have not attained to that, and that is to be a man. As for the girls who are assisting us this evening, they are stenographers and workers throughout the building. They feel that it is a real privilege to be able to take part in this meeting, and that it is an honor to them. They really believe that to serve in this capacity is most becoming, and we appreciate your appreciation of it. (Applause.)

F. S. PEABODY.—It is my great pleasure now to introduce Mr. W. L. Saunders. He is a Past President of the Institute, and has been associated with the Ingersoll-Rand Co. as its President and as Chairman of the Board of Directors. He has been very active in Institute affairs and has taken part in many public movements connected with engineering in this country. He is now Chairman of the Naval Consulting Board.

The Naval Consulting Board in its Relation to the Navy Department

W. L. SAUNDERS.—I have been given 10 minutes to speak of the Naval Consulting Board; 5 is quite enough. I speak, alas, as one of experience when I say that a single sentence on this subject might stir up more trouble (for the speaker) than a ton of TNT. About a year ago, when I was only a freshman, serving the Government for glory and a dollar-a-year, I let fall a prophesy—prophesy is dangerous tramping ground for the tenderfoot. I said that American inventive genius would solve the submarine menace and that the Naval Consulting Board had already made substantial progress in that direction. Forthwith I fell into the hands of the Philistines—in modern terms called newspaper reporters. When it was all over and I recovered consciousness a Red Cross nurse seemed to be holding a glass of Jersey lightning to my lips. There is a story of an English Tommy who was convalescing from his first dose of trench warfare. A visitor at the hospital asked him to describe the wonderful sensation of being in a battle. He said, "First you 'ear an 'ell of a noise, then you 'ear the nurse say, 'You better drink a little of this.'"

Well, I fear that the German submarine, like the liar, the thief, the murderer and the rattlesnake, will be always with us in this war; but thanks to the English and American navies, aided by civilian workers, this dishonest practice no longer threatens starvation or disaster to civilized nations. The British Prime Minister is my authority for the statement that the submarine is no longer a menace, but is still a nuisance. Mr. Arthur Pollen adds that it is an awful nuisance. I should call it a damnable nuisance.

As to the part taken by the Naval Consulting Board, I quote from the recent Annual Report of the Secretary of the Navy.

The work of the board, organized and approved by Congress in 1915, has increased very materially in importance and volume. Some time before the active entry of this country in the war the board called a special meeting to which were

invited some 50 of the leading scientists and industrial managers, whose special study fitted them to advise on the methods of meeting the submarine problem. Plans were immediately made to investigate every field to develop a means of preventing destruction of vessels and of defeating the U-boat. The investigation was divided according to the experience of the different members and associated scientists; and with the coöperation and valuable assistance of the various manufacturing companies interested, a highly developed system of team work has been attained and results accomplished not dreamed of at the beginning of the war.

Valuable assistance has been rendered merchant shipping by the board's activities. Through its initiative, counsel and work, the U. S. Shipping Board formed its Ship Protection Committee, taking over the study of the protection of merchant ships, and to this Committee was detailed one of the Consulting Board's most experienced members qualified in shipbuilding and with sea experience. In this field the board's work has resulted in materially reducing the shipping risk, with a consequent lowering of marine insurance rates.

The board has stimulated interest in war problems. It has stirred a patriotic spirit and effort among inventors. More than 65,000 suggestions and plans have been considered and acted upon.

Our relations with the bureau chiefs and other officers of the Navy are most cordial. Individual members of the board, like naval attachés, are from time to time called into action to aid an executive in designing or building something of value in the war service. While there are many standing committees covering different fields of scientific work, yet each member is a committee unto himself in coöperating with naval officers.

Through the vision of Secretary Daniels, this board was created about a year and a half before the United States entered the war. This act of early preparedness resulted in the survey and listing of all the manufacturing industries of the country—a useful thing which had not been done before. That survey, fully card-indexed, is now serving its purpose, bringing promptly and efficiently all the resources of the nation to the aid of the Army and Navy.

More than this should not be said at the present time of the work of this board. If any one would like to ask questions I should be glad to answer them—after the war is over.

F. S. PEABODY.—The next gentleman I shall introduce was, prior to the war, Director of the Mellon Institute of Pittsburg, which was founded for industrial and chemical research. At the beginning of the war he took an active part in the early gas investigations of the Bureau of Mines, going from that work to join the Chemical Service Section of the Ordnance Division. He has recently returned from France, where he had charge of the field laboratory work on gas and flame fighting—Colonel Raymond F. Bacon.

COLONEL BACON.—I am in a somewhat awkward position tonight in trying to talk to you about gas. I think I can probably illustrate my position best by telling a little story.

You know the purpose of a trench raid is to obtain prisoners, so that opposing units may be identified and information of various kinds obtained. We had a great deal of trouble with the Americans, at first, to make them take prisoners. At one time quite a successful raid was pulled off and one very small American private was bringing in quite a large German officer. This officer had been slightly wounded in the heel,

and he was complaining a good deal about how rapidly he had to walk. The private was anxious to dispatch him, as had been the custom, but the officer in charge of the party said, "You know the orders are very strict; we must bring in prisoners." The rest of the party went on and finally the private came in all alone.

"Why, Private Mulligan, where is your prisoner?"

"Sir, the prisoner died of his wounds."

You have heard that food will win the war, that aeroplanes will win the war, and that ships will win the war—I also want to tell you that gas will win the war. By that I mean that gas is becoming a thing of primary importance.

It is interesting that this work was started by a mining engineer—by Mr. Manning, of the Bureau of Mines. He had the foresight to see that we must have a gas organization; he has gone ahead and has gathered one of the best galaxies of chemical stars that are to be found anywhere. These men are giving their whole time to providing better protection for our men against gas attacks, and to the discovery of better gases; and, while I may say nothing as to just what is being done, I can assure you that when the proper time arrives we shall be able to hand to the boche a little more hellish gas than he has ever handed us.

F. S. PEABODY.—The gentleman I shall next introduce is a real, genuine mining engineer, connected at one time with the Guggenheims. He graduated as an engineer from the Washington University, at St. Louis, after which he went to South Africa, where he became general manager of a large group of gold mines. When he returned he was placed in charge of the development and equipment of the Chuquicamata mine. He is now in charge of non-ferrous metals in the War Industries Board—Mr. Pope Yeatman.

The War Industries Board

POPE YEATMAN.—I have been asked to give a story of the War Industries Board, its formation, organization and work. In doing so, I wish to acknowledge the assistance given me by Mr. D. H. Van Doren of our Legal Department.

Organization of War Industries Board.—The Board consists of Mr. B. M. Baruch, Chairman, and 11 members or directors; a Price-fixing Committee, of which Mr. Robert S. Brookings is Chairman, consisting of eight members; a Labor Division; Conservation; Allied Purchasing; Finished Products; Raw Materials; Statistical; and a Priorities Division and Board.

Under the War Industries are numerous Commodity Sections, such as Agricultural Implements; Automotive Products; Brass and Copper Tubing; Building Materials; Chain; Chemicals and Explosives; Crane; Electric and Power Equipment; Emergency Construction; Hide, Leather and Tanning Material; Lumber; Machine Tool; Non-ferrous Metals; Small Tools and Hardware; Steel; Supplies; Tin; Tobacco; Wire and Cable; Wood Chemicals; Wools; and others.

Section heads are chosen for their business experience, or their possession of expert or technical knowledge; among these may be mentioned Messrs. J. Leonard Replogle, S. M. Vauclain, Everett Morss, Richard L. Humphrey, L. L. Summers, C. H. Connor, Frederic Darlington, R. H. Downman, Col. W. H. Starrett and Walter Robbins. With the

section heads are associated, as contact officers, men appointed from the Army, Navy, Emergency Fleet, Railroad Administration, etc.

The War Industries Board was formed under authority of the Council of National Defense, by resolution of July 28, 1917. It succeeded the General Munitions Board—the latter also an offshoot of the Council of National Defense, having been created by resolution of the Council of March 31, 1917.

The Board acts as a clearing house for the war industry needs of the Government, determines the most effective ways of meeting them, the best means of increasing production, including the creation and extension of industries, considers price factors, the industrial and labor aspects of problems involved, and the general questions affecting the purchase of commodities.

It might be mentioned here that the War Industries Board has not undertaken to classify any legitimate industry as non-essential, but only through the exercise of priority directions to insure supplying to direct and indirect war industries as nearly as possible 100 per cent. of their requirements.

The Board is opposed to the purchase, by foreign interests, of materials for export after the war, or to the launching of non-essential enterprises during the period of the war, and favors utilizing, for war purposes, those facilities now existing.

It has been the consistent policy of the War Industries Board to secure the friendly coöperation of American manufacturers and commercial interests wherever possible. It has recognized that sacrifices made willingly and intelligently by commercial interests have a great moral effect on the patriotism of the whole country, and has, therefore, made every effort to explain such steps as it seems desirable to take to representatives of the industries affected, and to receive suggestions from the latter calculated to increase efficiency in the work undertaken.

The first Chairman, Mr. Frank A. Scott, was later succeeded by Mr. Daniel C. Willard, and he, in turn, by Judge Robert S. Lovett. On March 4, 1918, the President addressed a letter to Mr. Bernard M. Baruch, offering him the Chairmanship of the War Industries Board, and at the same time outlining the functions of the Board and its Chairman. This letter, which constitutes the charter of the re-organized War Industries Board, is in part as follows:

THE WHITE HOUSE, MARCH 4, 1918.

MY DEAR MR. BARUCH:

I am writing to ask if you will not accept appointment as Chairman of the War Industries Board, and I am going to take the liberty at the same time of outlining the functions, the constitution and action of the board as I think they should now be established. The functions of the Board should be:

- (1) The creation of new facilities and the disclosing, if necessary the opening up, of new or additional sources of supply.
- (2) The conversion of existing facilities, where necessary, to new uses.
- (3) The studious conservation of resources and facilities by scientific, commercial and industrial economies.
- (4) Advice to the several purchasing agencies of the Government with regard to the prices to be paid.
- (5) The determination, wherever necessary, of priorities of production and of delivery and of the proportions of any given article to be made immediately accessible to the several purchasing agencies when the supply of that article is insufficient, either temporarily or permanently.
- (6) The making of purchases for the Allies.

The Board should be constituted as at present and should retain, so far as necessary and so far as consistent with the character and purposes of the re-organization, its present advisory agencies; but the ultimate decision of all questions, except the determination of prices, should rest always with the Chairman, the other members acting in a co-operative and advisory capacity. The further organization of advice I will indicate below. In the determination of priorities of production, when it is not possible to have the full supply of any article that is needed produced at once, the Chairman should be assisted, and so far as practicable, guided by the present priorities organization or its equivalent.

In the determination of priorities of delivery, when they must be determined, he should be assisted when necessary, in addition to the present advisory priorities organization, by the advice and co-operation of a committee constituted for the purpose and consisting of official representatives of the Food Administration, the Fuel Administration, the Railway Administration, The Shipping Board, and the War Trade Board, in order that when a priority of delivery has been determined there may be common, consistent, and concerted action to carry it into effect.

In the determination of prices the Chairman should be governed by the advice of a committee consisting, besides himself, of the members of the Board immediately charged with the study of raw materials and of manufactured products, of the labor member of the Board, of the Chairman of the Federal Trade Commission, the Chairman of the Tariff Commission, and the Fuel Administrator.

The Chairman should be constantly and systematically informed of all contracts, purchases and deliveries, in order that he may have always before him schematized analysis of the progress of business in the several supply divisions of the Government in all departments.

In brief, he should act as the general eye of all supply departments in the field of industry.

Cordially and sincerely yours,
WOODROW WILSON.

Mr. B. M. Baruch, having accepted the appointment as Chairman, undertook a reorganization of the War Industries Board along the lines indicated in the President's letter. In the *Official Bulletin* of April 8, 1918, announcement was made of a new Requirements Division of the War Industries Board, to coördinate the work of the various sections and other subdivisions of that body, with a view not only to meeting but to anticipating the emergency war needs of the United States.

Requirements Division.—The Requirements Division serves as a central directing agency in the machinery of the War Industries Board, through which the policies of the Chairman are to be carried out. It acts as a central information agency to obtain data as to all contracts, purchases and deliveries, so that the progress of business in the several divisions of the Government in all departments can be followed.

It is the duty of the Requirements Division to obtain information from the Supply Divisions of the Purchasing Departments and the Allied Purchasing Commission as to their respective needs for raw materials and finished products, and as far in advance as possible. The Requirements Division, in turn, delegates the task of fulfilling these needs to the special Commodity Sections of the War Industries Board, to the Supply Departments themselves, or to such other agencies as may be decided upon. It is composed of men appointed from the War Industries, the Army, Navy, Emergency Fleet, Food Administration, Railroad Administration, Red Cross, etc., and in addition others attend the daily meetings as necessity demands.

At these meetings the necessities of the Government are brought up and discussed, and means are proposed for overcoming difficulties, or avoiding them in advance.

The final responsibilities lie with the Section Chiefs, who come in direct contact with the special industries, hold frequent conferences

with them, and who, in coöperation with industrial heads, regulate the various industries, such regulation being usually carried on through committees formed from the principal officials of the different companies.

To take charge of particular problems of supply there have been created special Section Heads, to handle, wherever necessary, raw materials or finished products of which there is an actual or threatened shortage, or the price and production of which should be controlled for the protection of the United States Government, the Allies, or the civilian population.

It is the purpose of the chairman of the War Industries Board to make each of the Section Heads the sole Government agency for dealing with the industry for which his section is responsible, and it is the purpose of the chairman of the Board to centralize in each of these Section Heads all such tasks as the issuance of questionnaires and all other means of gathering information about the industries which each Section Head has in charge. Through these Section Heads, therefore, all data and information about particular industries will be focused, and in their offices the information will be at all times available to the several interested departments, to the Price-fixing Committee of the War Industries, to the Priorities Division of the Board, and to any other agency that may be designated by the Chairman of the War Industries Board.

Under each Section Head there are several Commodity Chiefs who study the problems surrounding their particular commodities and procure from all available sources, including the Supply Departments, information and data which will be helpful in the allocation of these requirements.

The Commodity Chief has certain definite duties. The first is the collection of information regarding industrial conditions already mentioned. Further, in pursuance to the President's directions to the Chairman of the War Industries Board, he considers from time to time the extent of the existing sources of production, the creation of new facilities, and the disclosure, if necessary the opening up, of additional sources of supply, and the conversion of existing facilities to new uses.

Each Commodity Chief considers market conditions pertaining to the materials or commodities over which he has jurisdiction, and, where deemed advisable, recommends purchase plans to the several purchasing departments. In cases where it becomes necessary to control an industry in whole or in part by means of allotments, the responsible Commodity Chief determines the allotments of materials and facilities to the several departments of this Government and to its Allies, and also the extent to which manufacturers and others, whether serving the civilian population or engaged in the manufacture of war supplies, shall be supplied.

Conservation Division.—The Conservation Division was established to succeed the Commercial Economy Board, the latter having been under the auspices of the Council of National Defense, and formed for the task of promoting economy in our industrial life. Plans for conservation were carried out in the past year in the clothing, garment, shoe, paint, agricultural implement, and other industries, and in various wholesale and retail trades. The aims of the Board are to determine by careful investigation what less essential uses of labor, material, equipment and capital can be dispensed with in time of war. It is considered far more practicable to eliminate the wasteful or unnecessary uses of labor, material, equipment and capital in all kinds of business rather than to have any business specified as non-essential. There is hardly a business which

can be called entirely non-essential, but every industry uses some of our resources or facilities for purposes which are not essential in time of war. The Conservation Division has sought to foresee conditions that needed to be met and to deal with them forehandedly so as to prevent, so far as possible, shocks to our business structure or severe and sudden labor dislocations.

Priorities.—The duties of the Priorities Board are to determine general principles and define basic rules which shall govern priorities of production and delivery of materials, equipment, and supplies, and to carry such determinations into effect. The Priorities Board from time to time promulgates in the form of "preference lists" not only classes of industries, but individual plants whose operations as a war measure are of exceptional importance and which will be classified, as far as possible, in the order of their relative urgency measured by the extent of their direct or indirect contributions toward winning the war and toward promoting the national welfare.

The War Industries Board resolved on March 21, 1918, that all new undertakings not essential to and not contributing either directly or indirectly toward winning the War, which involve the utilization of labor, material and capital required in the production, supply or distribution of direct or indirect war need, will be discouraged, notwithstanding the fact that they may be of local importance and of a character which should, in normal times, meet with every encouragement. It was further resolved, that, in fairness to those interested therein, notice should be given that the Board would withhold from such projects priority assistance, without which new construction of the character mentioned would frequently be found impracticable.

The War Industries Board earnestly urges each non-war industry to look this situation squarely in the face and plan accordingly, curtailing where necessary operations not falling within the general classification of purposes demanding preferential treatment, and at the same time, where practicable, converting existing facilities and utilizing existing organization for purposes entitled to preferential treatment, thus reducing the damage to industry to a minimum, and at the same time relieving some of the war industries that are staggering under the abnormal burdens which they are carrying.

The Priorities Board does not undertake to administer priority on coal or coke, which are handled by Dr. Garfield, the U. S. Fuel Administrator; nor on foods or feed, which are in charge of Food Administrator Hoover. No blanket priority certificates have been allowed.

The paramount purpose of priorities is the selective mobilization of the products of the soil, the mines, and the factories for direct and indirect needs in such a way as will most effectually contribute toward winning the war. The sole object of this division is to render a very real service to the Government and to the Nation, within the scope of its activities. The general policy of the Committee is to decline to give priority for replacement or maintenance of stocks. No priority assistance will be given to new industrial plants and public improvements unless the construction is essential.

Allied Purchasing Commission.—One of the most important divisions of the War Industries Board is that in connection with purchasing for the Allies. The President, in a meeting with the War Industries Board, held August 6, 1917, stated that "The Allies should receive the same

prices on military materials which this country paid for its military requirements, provided, of course, that reciprocal action on the part of the Allies, not only toward this country but toward each other, was arranged for." Arrangements were made in August, 1917, by the Secretary of the Treasury with the Governments of Great Britain, France, Italy, Belgium, Serbia, and Russia, regarding the purchasing of supplies for those governments in the United States. All of these arrangements are identical and all are now in force, except that with Russia.

Purchases are made by representatives of foreign Governments direct, but only with the approval of the Purchasing Commission.

All purchases of food stuffs, forage, and food, are made through the U. S. Food Administrator. All other purchases are made subject to the approval of the War Industries Board.

Price-fixing.—In the President's letter of March 4, 1918, dealing with the powers and duties of the recognized War Industries Board, he also provided for the creation of a Price-fixing Committee, stating:

In the determination of prices, the Chairman should be governed by the advice of a committee consisting, besides himself, of the members of the Board immediately charged with the study of raw materials and of manufactured products, of the labor member of the Board, of the Chairman of the Federal Trade Commission, the Chairman of the Tariff Commission, and the Fuel Administrator.

As outlined by the Chairman of the War Industries Board, the duties of this Committee are as follows:

1. The Committee will advise upon prices of basic materials.
2. From time to time advise as to general price policies, acting in this way as a coordinating price body.
3. To advise when requested by any department upon a specific contract, assuming, however, that no department will submit for advice those problems which it is organized and qualified to handle itself.
4. Where it is necessary to resort to commandeering, the committee will be called upon to fix the prices to be paid for the materials commandeered.

Prices are fixed by agreement, with commandeering as an alternative.

In the absence of statutory authorization for the fixing of compulsory prices by the Government (other than food or fuel), it has been the policy of the War Industries Board, both before and since the Price-fixing Committee began its work, to enter into agreements with the producers of articles for which the Government's needs are imperative, as to the prices to be charged. These price-fixing agreements are voluntary on the part of the producers, but if no agreement can be reached or if producers fail to abide by one when made, the Government may exercise its power of commandeering the needed supplies. Commandeering is not, however, to be used when amicable arrangements with producers can be made. Quoting from the President's statement in August last: "Prices for military materials for this Government and the Allies should be arrived at by negotiations with producers," and only as a last resort did he wish commandeering to be used.

At the time the price for copper was first fixed, in September, 1917, the statement for the press issued by the Board contained this sentence:

"The proper departments of the Government will be asked to take over the mines and plants of any producers who fail to conform to the arrangements and price, if any such there should be."

Price-fixing by the War Industries Board has been of two sorts first, fixing prices that the Government only is to pay; and second, fixing prices for the Government, the Allies, and the public. In the

latter case, the price-fixing agreements hitherto made have generally been accompanied by certain conditions or guarantees to which the producers agree. These conditions are as follows:

First, that the producers would not reduce the wages now being paid;

Second, that the operators shall sell to the Government, the Allies and the public at the same price and will take the necessary measures, under the direction of the War Industries Board, for the distribution of the product, and to prevent it from falling into the hands of speculators who might increase the price to the public;

Third, that the operators pledge themselves to exert every effort necessary to keep up production to the maximum of the past so long as the war lasts.

The problem of the Price-fixing Committee is to stabilize prices. The general economic interest of the Nation is to stabilize all values, not with a view of reducing them to anything like pre-war conditions, and recognizing the fact that we are upon a higher general basis, but to prevent what might be termed a run-away market. Discouragement of speculation has been a policy of the Price-fixing Committee. At the meeting of May 14, the Chairman of the Price-fixing Committee stated: "In fixing prices there is no intention of interfering in any way with existing contracts. Prices fixed are only maximum prices; producers can sell for less if they choose."

In all its dealings with the industries, it is a great inspiration for those connected with the War Industries Board to find such patriotism and desire on the part of the officials of the different industries to coöperate with the Government and help in every way possible. This interest in a common cause also draws together in a remarkable way competitors who previously have been antagonists. Not only is this noticeable with men in the same branches, such as smelters, but also with those old-time enemies—the producer and consumer. Men are willing to turn over their business to the Government and practically to give up everything they have to aid the cause. Even with all these higher feelings, the old Adam often appears in the desire to get everything possible out of a bargain. This is not unnatural, for the ordinary business man's success lies in his making good bargains and his education has been in that direction; so that when his game is to be played, his pride and his habit compel him to play with his old-time spirit and knowledge of the trade, and though willing to give up all his profits, at the same time he is unwilling to lose the prestige of a good business deal. At first sight this may seem contradictory with his real feeling for the Government, but really it is not so.

Mr. Baruch wishes me to express to you his great appreciation of what the mining engineers have done, not only in going into the Army and fighting in the trenches, but also in helping the Government in civil capacities. He realizes the ability, progressiveness, and adaptability resulting from the engineer's education in the field, among the deserts and mountains, and in far-away places generally, and from experiences which have thrown him on his own resources and placed on him responsibilities shared by men of perhaps no other class. This experience has made the mining engineer a most useful man for aiding his Government in times when everything is topsy-turvy, and the formation of new organizations and the re-organization of old ones is necessary.

Mr. Baruch also wishes me to express his great appreciation for the patriotic action shown by men in the different industries, such as John D. Ryan and Daniel Guggenheim of the copper industry, whose action

at the beginning of the war, in offering their product at a very much lower price—16 $\frac{3}{4}$ c. as against 29 c.—for Government needs, proved a great moral force at a psychological moment, and made possible the carrying out of the Government program of coöperation between the different industries and the Government itself.

We have often been asked what is the actual power of the War Industries Board, or the legal status of the Board in its regulation of the different industries. As you know, the work was at first advisory, but later it became executive or administrative. The power lies through the power of the President, as Commander in Chief, to commandeer, this being done through the right of the Army and Navy and the Shipping Board, conferred by act of Congress. In addition, and perhaps the most effective force toward securing coöperation, is the feeling of patriotism and the wish to help the country. Regulation is also obtained by priority in delivery of supplies, and the shipping of products, by embargoes, and by export and import licenses. At the bottom of the whole matter, however, lies patriotism, and the desire to help the Government win the war.

F. S. PEABODY.—Not wishing to disgrace my Chief, and realizing how little I knew about scientific matters, when I received his telegram the other day in Halifax, ordering me to be here, I procured at once all the scientific books I could get a-hold of. I got a Saturday Evening Post, a new novel by Oppenheim, a book by Maeterlinck, and Emerson's Essays, too; and, really, I have been doing my best to prepare myself for this evening. I have also read Sir Robert Stowell's "The Earth's Beginnings." I have got two good things out of Stowell, and the first is this: Suppose that we extracted from this earth every ton of coal which it possesses from every isle and every continent. Suppose that this mighty store of fuel, sufficient to supply all the wants of the earth for centuries, were to be accumulated and that by some mighty effort that mass were to be hurled into the sun and were forthwith to be burnt to ashes. There is no doubt that a stupendous quantity of heat would be produced. But what is that heat in comparison—we do not say with the heat of the sun—but with the daily expenditure of the sun's heat? How long think you would the combustion of so vast a mass of fuel provide for the sun's expenditure? We are giving deliberate expression to a scientific fact when we say that a conflagration which destroyed every particle of coal contained in this earth would not generate as much heat as the sun lavishes in the tenth part of every second.

I take great pleasure in introducing to you the representative of what I think is the most important industry in the United States today—Mr. Norris, who represents Mr. Garfield.

R. V. NORRIS.—I ought not to represent the Fuel Administration. The Fuel Administration is composed of mining engineers. Of the Executive Department, six out of eight are members of this Institute; the Assistant Administrator is a member of the Institute, and also the head of the Oil Department. I am only a deckhand, haven't any business to be here at all.

The Fuel Administration was bumped into office at a time when the coal business had gone wild. Coal was selling at any price that anybody chose to offer, and the higher the price, the less coal you got. The prices were ranging from \$4 or \$5 to \$8 or \$10 for coal that ordinarily sold at \$1.50, and something had to be done. It was not only a case of pro-

fiteering, but it was actual shortage; and we still have the shortage today, and I am afraid, gentlemen, we are going to have it for some time.

The situation is serious. We have been pinning the bouquet on the railroads. The railroads maybe deserve some of the blame for the lack of transportation, though a whole lot of the trouble is caused by shortage of labor. Do you realize that with a 30 per cent. shortage of labor the coal business has increased 20 per cent.? This means that a most tremendous effort has been made not only by the owners of the coal mines, but by the laborers also. Labor is doing its bit; it isn't doing all we want it to do, but one of the eminent executives of the Coal Administration is working day and night on propaganda to increase the efficiency of labor, and the amount of work that the laborer will do.

The Fuel Administration has, by a zoning system, so arranged the amount of cross-hauling as to save about 160,000,000 car-miles a year. That is equivalent to adding 5 per cent. to the production of bituminous coal. By the efforts which are now being successfully made to produce clean coal, I believe that at least 10 per cent. more coal is available with the same transportation. It is hard fact to state, but I believe there is no doubt that Mr. Manning was entirely correct when he stated that the increase in production recorded last year was not an increase in coal but an increase in slate. It is not going to be an increase in slate this year, and we are ahead of the game a little; we ought, however, to be a lot further ahead of it.

Another feature of the Fuel Administration's work has been the fixing of prices, which has been as difficult a proposition as has been given to any Administrator. It was not so simple as in the War Industries Board, where prices were fixed by agreement with the producers of commodities. On the contrary, the fixing has had to be compelled. It has been based, however, absolutely on the reports of the producers themselves. The Federal Trade Commission has required from every coal mine operator in the United States, large or small, a monthly report of his costs and returns. On the basis of those costs, and on consideration of the character of the coal, of the geological conditions, of the thickness of the beds, the country has been districted, and prices have been fixed to give to miners of all necessary coal a reasonable and just profit.

This has been done by tabulating and plotting the costs of each district, and fixing prices based on the production of the necessary coal, at a reasonable profit. An average cannot be used; for this would mean that half of the output would be produced at a loss or at less than a reasonable profit.

In going over these sheets we have learned some rather amusing details. In one case where the Trade Commission's sheet required the amount and value of fuel, two operators in Missouri reported under this heading their mule feed. An operator in my own State, Pennsylvania, returned his sheet, and in the bottom corner, under "Tonnage," was 27, and below that in pencil: "Federal Trade Commission, Gentlemen: We ain't got much of a mine. Me and my son and two hired men runs it. We pays cash for what we gets and sells our coal for cash and don't keep no accounts but at the end of the month we divides the money; sometimes there ain't none to divide."

The whole price fixing scheme could have been avoided by the very wise plan proposed by our toastmaster, and Mr. Lane. Their scheme was to fix a maximum price—a price sufficient to stimulate the industry,

so that the law of supply and demand would act. There would have been no occasion for price fixing if that had been done. I will say further that the weighted average of the prices in effect today is within 25 c. of the price proposed by that agreement.

F. S. PEABODY.—The next man (or superman) I am to introduce is one whose name is known from one end of the world to the other; whose wisdom has helped more people than any other's on earth—Mr. Hoover.

The Food Administration

H. C. HOOVER.—After that, I cannot say that I do not feel entirely out of place in this meeting. I have addressed mining engineers before but I do not know that I have ever talked to my own profession on a subject so far from their ordinary course of professional work. I little dreamed 4 years ago that I should be so far afield as I have now drifted. On the other hand, I have hopes still that some day I may return to that profession, and there are times in the Food Administration when it looks imminent enough. This is admitted in every country to be the most obnoxious of administrative jobs and one fraught with no satisfactions. However, we have no right to complain over our troubles while our fellow countrymen are making the supreme sacrifice.

We have, myself and my seven mining engineer colleagues of this Administration, now lasted for a matter of about 13 months. In so doing we have attained the longest record of any single Food Administration in the world. (Applause.) Before I was summoned to come home and undertake this work I had some indication of what I was being asked to come for, and I had various meetings in Europe with my subsequent food control colleagues to determine something of the problem that we had to undertake at this end. I regret to say that all of those gentlemen have passed into private life, owing to the high mortality that surrounds food controllers. (Laughter.) But the problem has not changed. We have, however, in the Food Administration 13 months of experience and we have traveled a long way. We can now see with rather more clearness than ever before what our problem is and we can point to a certain amount of accomplishment.

At that time in Europe, 13 months ago, we were well possessed of the seriousness of the food situation in the entire world. From our point of view it fell into two parts—that food situation inside of the German controlled territory and the food situation outside of it. The situation inside affected us in many ways. First, from a military point of view, that we should draw the starvation line as stringently as we could about the Central Empires and that yet we should vary this so far as we could to protect those Allied peoples who had been over-run by the Germans, and the neutrals who bordered them.

At that time, and now, some three hundred millions of people were under the control of the German empire and their associates. Of those people, something like 50,000,000 were Allied people over-run by the Germans and the Austrians, and the enemy was living to a considerable degree on the foodstuffs that they succeeded in getting away from the people whom they had crushed. They have continued to reduce the food supply of those people so greatly that the actual death rate in Europe today, from starvation and under-nutrition amongst those over-run peoples, is larger than the actual mortality on the battlefield.

That was but one feature of the Germans' work. Not only had they reduced this 50,000,000 people, and their own population as well, to a state of semi-starvation, but they had reduced another three or four hundred millions of people in this world to food difficulties. The German submarine had made such inroads in shipping at that time, and was out-running the construction of ships at such a pace, that we had but one solution to our problem. There is a sufficiency, and was at that time an ample sufficiency, of food in the world available to seaboard to support the Allied nations without the necessity of any restriction of any kind, but shipping was so reduced and prospects of further reduction were such that the one hope of keeping the Allied nations supplied with food rested upon North America. Australia was then practically abandoned as a source of food supply, the East was stocked with foods that were inaccessible, the Argentine was only partly available. We had to reduce the food supply of the Allies to that amount that could be transported in a large degree from North America as the nearest market.

Prior to the war this country supplied something like 10 per cent. of the imported food in the Allied countries; North America has lately supplied over 50 per cent.

With an international balance sheet in front of us, we felt that only by a great saving in North America could a remedy be afforded. Furthermore, we realized then, and we realize now, that the continuous decrease in shipping and the increased demand in shipping to transport the American Army would steadily impose an increasing burden on the North American continent. A great tonnage of ships has been saved. If we could take on our backs next year the entire problem of feeding the Allies with imported food, we will have saved approximately a further 1,500,000 or 1,750,000 tons of shipping over the amount that has been required in the last 12 months to transport the one-half that has come from the more remote markets. Not only was reduced consumption necessary in the United States, but also increased production.

Now, in considering the stimulation of production in the United States, I felt that the prime factor in production is price. Production—normal production—is based upon the profit productivity of a certain definite area. An increased price is necessary to increase the area under production. In other words, any increase of production must fundamentally arise from an increased marginal area that can be brought under cultivation at a higher cost; and therefore it was fundamental that we should establish and maintain a range of price that would bring into play full marginal production of food from the United States.

This, then, is, to a considerable degree, the cause of the high price level of food. We entered into this war after the harvest had been largely planned and were unable to do much in the way of stimulating production last year. Besides that, we had a bad harvest year. Our wheat crop was far below normal and our corn crop in 40 per cent. failed to mature. We had not only to face export increases but an actual shortage in supplies. We had a certain resiliency in the United States in food consumption. We are the most extravagant people in the world in consumption and waste, and we have, therefore, sought to balance our world account by reduction of consumption and the elimination of waste.

We have exported from this country more food to the Allies than ever before against our deficiencies in production.

It is too early yet to speak with certainty as to the harvest. However, the prospects are for the largest total crop ever produced. (Applause.) We now have the largest area under cultivation the United States has ever seen.

The privation in consumption amongst the Allies has been very great and we are in hopes that next year we shall be able to provide them full bread supply, and it is believed that nothing will so lift the morale of the population of Europe as to feel that there is no longer any concern about their food problems. (Applause.)

An example of the response of the American people may be pointed to in the matter of pork products. During the last half of 1917 (the first 6 months of our work), we were exporting only an average of 80,000,000 lb. of pork products per month—far below the requirements of the Allies. With the opening up of the railroads after the storm period at the end of February, we began to export at the rate of 300,000,000 lb. per month, and we have maintained that since—have maintained that rate of export out of the old hogs, not the new, and in addition our storage has increased from 600,000,000 lb. to 1,200,000,000 lb. In addition to that, we have millions of little pigs coming on to increase our production. The Department of Agriculture is performing wonders in this stimulation.

During the latter part of February, the average number of people waiting in the lines outside the meat shops in England for rations is given as 1,800,000. During the month of May these lines had been reduced to an average of less than 2000 in a day. This itself is the picture of diminished and then redeemed supplies.

This great addition in food supplies which we were able to bring into force about the end of February reached Europe at the time when the great German drive began, and has had much to do with maintenance of morale in that extremely trying time.

While we try to maintain a high price level to stimulate the producer, we try to eliminate all vicious speculation in foodstuffs. I do not believe there is any consequential profiteering in food today. Some concerns earn large profits, but in times of shortage all concerns must be kept in production and a basis that will protect the high-cost producer must leave large margins to the low-cost man. Taxation alone can correct this.

We have a large number of charts in our work. One of them represents the real price factors in food. You all know that there are many published indexes of food prices. All these various indexes have been prepared, taking some definite period as a criterion and adding price factors together regardless of their weighted value. We have invented a new index by which we represent a weighted value in price movements between the different foodstuffs. We have taken as the common denominator the nutritive values of food, not the quantity. In the application of that index we show the relative importance of foods and in applying that index we find there has been, since last May, an increase of 18 per cent. in the price of foodstuffs to the producer. At the same time there has been a decrease of 12 per cent. to the consumer. The margin has, therefore, diminished by 30 per cent. That margin represented practically the vicious speculation that took place in this country in the marketing of food. The Food Administration has, theoretically, no price control. We have effected many voluntary agreements and by the

control of Government buying of certain commodities and the requisitioning of foodstuffs, we have done a good deal to stabilize prices.

There has been a great deal of discussion about the whole question of price fixing. There is a total lack of recognition of the new economic factor coming into the world, not only an economic but a moral factor. In the first place, this critical group, and it is a very large group, believes the stimulation of production and reduction of consumption can best be effected by allowing prices to rise. Conservation by high prices is conservation for the rich, not the poor. (Applause.)

There is a point in price where you cover the stimulative margin to production. Beyond that point the consumer deserves every consideration. If prices rise to an unlimited degree you get conservation simply by the inability of people of shortened means to purchase. That is the moral factor. The other economic factor that dominates our situation is this: that we are dominating the purchase of such a quantity of food that the mere purchase of that quantity dominates the price. And there is the new economic factor. Economists have dealt for years with combinations in control of distribution, but no economist ever conceived that there would be a consolidation of purchase so great that it could dominate price.

In the matter of wheat, for instance, we fixed the price practically by the fact that we are the purchasers of 35 or 40 per cent. of the wheat in the United States. It is within our power, by the manipulation of that purchasing ability, to decrease or raise the price as much as we will. We have, however, felt that in fairness to the community we should not use that power but that we should establish what we call a fair price that is known to every mortal soul in the United States, and that we should stick to the price and use those purchases to effect it.

In the matter of some other food commodities our purchases are now so large that we influence the price. We have here, in this Administration, direction of the policies in the consolidated buying of the Army and Navy, of all of the Allies, and of all the neutrals. That consolidated buying passing through our hands today amounts to nearly \$400,000,000 a month and it comprises one of the considerable energies of the Food Administration. I am happy to say that after one year we had no suggestion that one cent of that has ever been mishandled or misspent.

Now, the Food Administration is founded on voluntary service. We ask for voluntary service from the producer, with the stimulation and certainty of a market at a fair and just price, for we have endeavored to stimulate the producer with a national service. We have spread propaganda from one end of this country to the other on the duty of the producer. Likewise, we have spread propaganda on the duty of the consumer. Further than that we have organized the distributing trades in the United States, also on a voluntary basis. We have a great deal of power over the distributing trades, but in every case where we have laid down rules and regulations under the law those rules and regulations have been drawn up with a view to maintenance of trades in their occupations. We have had comparatively little enforcement to do. I noticed the other day a statement that in Germany, during the past 12 months, there have been over 450,000 prosecutions for violations of their food law. We have actually had prosecutions here, with penalty, of 287 cases during the past year. (Applause.)

That voluntary service is one of the greatest tributes that has ever

yet been paid to a people. There is no other country in the world where the amount of service that has been given to the food problem could have been summoned from a population. There is no other place in the world where the average intelligence and the average in education and understanding is so high as to enable that to be done.

We have had the feeling—I have, and all the members of the Food Administration—that we were contributing more than the actual results that we turn out from day to day, which are measurable, in fact, by the exports that pass through our ports, and that is that we are making here an actual contribution to democracy, that we are not endeavoring to set up an autocracy, to dictate to this country, that we are actually endeavoring to educate the American people to the necessities of a war problem, to the fact that we are depending upon their own initiative to carry those things into effect. That I conceive to be the prime essence of democracy itself. If we were to establish here an administration of the German type we would have made a contribution to autocracy of the United States, we would probably have made a contribution to brutality. But as it stands today we believe that we have not only preserved but have stimulated the individual initiative, the willingness to self-sacrifice in the whole American people. (Applause.)

F. S. PEABODY.—I will now introduce your President, Mr. Jennings.

SIDNEY JENNINGS.—It has been a great pleasure and inspiration to me to attend this meeting, and hear the members of this Institute tell us what they have been doing to help win the war and defeat the Huns. It has been a source of inspiration to know that their work is to continue and that victory is ultimately coming to us.

We should try to see what is going to happen to this country after that victory has been won. In all the statements we have listened to tonight one refrain has predominated, and that is, labor troubles; I wish we could all keep on thinking and trying to solve that most difficult problem—the relationship between capital and labor. If we as an Institute, or as members individually, can help in the solution of that problem in anything like the measure in which our members have helped toward winning this war, the effect on the Institute will be a radiant one. Our membership will increase and the pride we feel as members of such an Institute will be great. Let us hope that we can accomplish that.

Today, at the meeting of the Board of Directors, a petition was received from the local members of Washington to form a local section, and it is a great pleasure to me, as President, to be able to announce a unanimous vote from the Board of Directors authorizing that formation. I am sure we wish every success to this new Section, the fifteenth Section of the Institute. It is by means of the interest aroused by these Sections that the growth of the Institute is stimulated, and I trust each member will try to obtain, during the coming six months, one new member of the Institute.

Another thing I would like to bring to your attention is the proposed change in the name of the Institute, which will be submitted to the members. It has been suggested that the name of the Institute be changed to that of "American Institute of Mining and Metallurgical Engineers." This will give to one-third of our membership that consideration which is due them.

HARVEY S. MUDD, *Secretary*.

WOMAN'S AUXILIARY

AMERICANIZE THE MINING INDUSTRY

Americanization is the making of American citizens; men and women controlled by the ideals of American citizenship, which have been built up by this country's heritage and its unceasing struggle for freedom and democracy and opportunity. That means, first of all, a necessary understanding of what those ideals are and what they mean for the newly arrived foreigner. It means that every kind of anti-American propaganda must be stamped out; that racial prejudices and the misunderstandings which lead to unrest and disloyalty and make fruitful soil for anti-American propaganda must be overcome.

The foreigner must understand. He must understand what we are trying to do here in America; he must understand something, at least, of the kind of government we have built up in our efforts to accomplish our particular aims; he must understand how he can fit into it all, not only to help America, but to help himself—to make it possible for him to get from this country what he came here seeking.

First of all, he must learn the American language. He must be able to talk with his fellow Americans—those who were born here and those who have recently come, like himself, but from a different land.

The most dramatic, the most crucial demonstration of the urgency of the need of all this is given to us right now. At the time when it is most essential for this country to be solidly American, enemy propagandists are winning an occasional success here because they give their message to men and women and boys and girls who do not understand our language and consequently do not understand us.

These foreigners, whom the enemy is trying to make disloyal, are really in our army, the big army that is fighting the war for America. Most of them are not among the soldiers who will fight on the battle front, but they are in the lines back of these soldiers. The worker in the shipyards and in the mines is just as important a soldier in this war as the man in the trenches. That has been said over and over, but it cannot be said too often. It is just as vital for that man in the mine to know why we are at war as it is for the soldier. His employer has just as great a responsibility to the country as has any general, and it is the same responsibility.

No native American citizen knows the curse of an oppressive autocracy as do some of these foreigners working in the mines. They will understand readily enough why we are at war if it is put before them carefully. This has been proved all over the country—in Liberty Loan campaigns, Red Cross drives, and the cantonments of our Army. And at the same time they will be getting a grip on Americanism which is going to outlast the war and be of tremendous value in the days that follow it.

But Americanism means, too, a responsibility, as an American, resting on those who have it in their power to protect or to exploit the immigrant. It is not living up to American ideals to discriminate against the foreigner in the matter of housing, for example, and in turn it works against the making a good American of that foreigner.

Americanization, then, requires:

The understanding of our language and the ability to use it.

The understanding of our social, industrial, and political ideas and ideals.

The acceptance of these ideals and the realization that they mean benefit to the foreigner personally and to his people.

The acceptance of this country as a home, not a temporary stopping place.

The realization that we are at war in order to preserve these ideals.

The appreciation that as an American, having chosen this country as his home, it is the part of every foreign-born resident to put himself back of the war, which is for him as much as for any of us, whether he be in the battle line or in the mine.

The employer who fails to appreciate these things and to make every effort to get them to his men is, at least, a negligent general in time of war and is truly endangering his country's fight.

In this bulletin we shall present, from month to month, statements of industrial Americanization. The methods used by some of the largest and most successful mines in the United States will be indicated; also the plans used by other industries which can be adapted to the conditions of mining.

Accounts of Americanization work done by mine managers will be received by the editor of this department, and printed. This should be a clearing house of ideas for companies that employ foreign labor. Write and tell us what your company has done in this line; describe methods and indicate results.

MRS. CLARENCE C. BURGER, *Chairman, Americanization Committee.*

AFFILIATED STUDENT SOCIETIES

MISSOURI SCHOOL OF MINES

The Missouri Mining Association has enjoyed a very good year. Last October the society was reorganized and the following officers elected for the year:

E. ROSS HOUSHOLDER, *President,*
ORE N. MANESS, *Vice-president,*
WILLIAM REBER, *Secretary,*
RUAL CHAVEZ, *Treasurer.*

The head of our mining department, Prof. C. E. Forbes, is now serving as a Major in the United States Army. We were fortunate in having Prof. Chas. E. Locke, of Boston, with us for part of the winter to take charge of the senior mining work.

During the autumn and winter months we had a number of informal smoker lectures in Norwood Hall. Among the speakers at these meetings were: H. A. Buehler, Missouri State Geologist; Chas. E. Locke, Boston, Mass.; V. H. Hughes, Tulsa, Okla.; Dorsey Lyon, Washington, D. C.; Prof. G. H. Cox, Professor of Geology, Rolla, Mo.; together with a number of returned alumni.

The seniors appreciated the fact that they were able to attend the St. Louis meeting last October.

The Association always encourages the upper classmen and alumni to join the Institute, and we claim to have more members than any other mining school.

WILLIAM REBER, *Secretary.*

OTHER SOCIETIES

DULUTH ENGINEERS' CLUB

The engineers of Duluth, Minn., have taken the first steps to form a Duluth Engineers' Club by a meeting on May 20, at the Kitchi Gammi Club.

At present, Duluth has no club embracing all engineers, although the environment is splendid for the growth of an engineers' organization.

Within reasonable distance of Duluth are over 100 members of the four large national engineering societies, a number of members of the lesser engineering societies, and many non-member engineers. Until the Duluth Association of Civil Engineers was formed, four years ago, these engineers had no common ground of meeting, and a force representing education, experience, and high ideals lay dormant.

About 70 engineers were present at the organization meeting, and favorable responses were received from others who could not be present. F. E. House, President of the Duluth & Iron Range Railroad, outlined the objects of the meeting, calling attention to the importance of the engineer in all lines of activity in the war and the splendid qualities of American engineers in France. W. H. Woodbury outlined the plan, stating the three objects of the club as professional, social, and civic. Four plans of membership have been considered: First, an organization for all professional engineers, junior engineers, and associates, with different status for each; second, an organization of members of the four big national societies; third, an organization of members and a limited number of associates; fourth, professional engineers, only, all on equal standing.

A resolution was offered by T. W. Hugo, Emeritus Member of the American Society of Mechanical Engineers, that it was the sense of those at the gathering that steps should be taken to form an Engineers' Club in Duluth, and that a committee be appointed to develop the plan. This was passed unanimously. Mr. House appointed a committee of eight representative engineers, of whom those representing the American Institute of Mining Engineers are Edwin J. Collins, and Walter G. Swart.

While it is recognized that engineers are busy with war activities and responsibilities, it is felt here that this is the time to unite the whole profession in one effective body promoting the interests and welfare of the profession and rendering service to the community. War has shown the great responsibility and opportunity of engineers to direct and do the work of the nation. It has emphasized the lack of complete unity of the profession both locally and nationally.

The progress made by the national engineering societies in unifying their efforts toward securing the proper recognition and employment of their talents to the fullest degree has been reflected by many cities in the formation of strong, well conceived engineers' clubs which have even advanced further in their work for the profession.

Duluth has a large list of engineers of high standing as individuals and the leaders of the movement for a club are very optimistic of the strength and success possible.

The program of the night included addresses by men of nation-wide reputation.

DIED IN SERVICE

Bailey, Lewis Newton, Master Engineer, Senior Grade, 4th Regiment, U. S. Engineers, Headquarters Company, died of pneumonia at Camp Merritt, N. J., on April 30, 1918.

Baird, Louis, Lieut., Royal Field Artillery, British Army, died on the battlefield in 1915.

Cobeldick, William Morley, Royal Engineers, died from gas poisoning on October 7, 1915.

Dougall, Ralph, killed in action.

Evans, Alfred Winter, Lieut.-Col., New Zealand Rifle Brigade, D. S. O., D. C. M., killed in action on October 12, 1917.

Hague, William, 1st Lieut., Engineer Officers' Reserve Corps, died in active service.

Hall, William T., Capt., Royal Flying Corps, killed in action.

Perry, Edward H., 1st Lieut., Co. D, 6th Regiment Engineers, U. S. Expeditionary Forces, France, killed in action on March 30, 1918.

Pretyman, Frank Remington, 2d Lieut., Royal Engineers, killed in action on June 17, 1916.

Reece, Fred. B., Capt., Royal Engineers, B. E. F., 232d Army Troops Co., killed in action.

Roper, George, Jr., Lieut., Royal Flying Corps, killed in aero accident in England on May 25, 1918.

NEWS FROM MEMBERS AT THE FRONT

Professor Sir John Cadman, K. C. M. G. (1918) D. Sc., F. G. S., M. Inst. C. E., was for two years Technical Adviser of the Chemical Warfare Department and Liaison Officer between British and French Forces. The Cross of Officer of the Legion of Honor was awarded him in 1917 by the President of the French Republic "in recognition of valuable services rendered by him in the cause of the Allies." At the moment, Sir John is Director of the Petroleum Executive and Chairman of the Inter-Allied Petroleum Conference. In 1915, he was Technical Adviser of the French Warfare Supply Department and was awarded C. M. G. in 1916.

J. Edwards-Leckie, C. M. G., D. S. O., went to Valcartier as second in command of the 72d Regiment, Seaforth Highlanders of Canada, with rank of Major, and later sailed for France as second in command of the unit now known as the 16th Battalion, the Canadian Scottish. He was promoted to Lieutenant-Colonel on Aug. 14, 1915, and returned to England to take command of the 2d Canadian Reserve Training Brigade at Shornecliffe. On Jan. 2, 1916, he was promoted to Colonel.

R. G. Edwards-Leckie, Lieut.-Col. of the 72d Regiment, Seaforth Highlanders of Canada (which unit later became known as the 16th Battalion, The Canadian Scottish, and under that name distinguished itself in France), left Canada for "Over There" on Sept. 14, 1914. He was promoted in France to the rank of Brigadier-General on Aug. 14, 1915, and served until severely wounded in February, 1916. He was Acting Chief of the General Staff, Canadian Overseas Forces in England from September to December, 1916. He returned to Canada in May,

1917, to take the post of General Officer Commanding, Military District No. 11, Victoria, B. C., with the rank of Major General.

J. C. Farrant was a Naval Volunteer and had attained the rank of A. B. (Able Seaman) some years before war broke out. Having business in the United States, he sent in his papers and got his discharge from the Naval Volunteers. In 1913 he returned to England and, while still keen on his naval work, felt that business demanded all his time and did not rejoin the R. N. V. R.

On Aug. 2, 1914, two days before war was declared, knowing that England would need all her fighting men, Mr. Farrant applied at the R. N. V. R. for his former position in his old company. He was told that he must join as a recruit. This he did, and after some months of strenuous work was again back in his old company.

Mr. Farrant was one of the Naval Division that was sent out to help at the siege of Antwerp and was taken prisoner by the Germans on Oct. 8, 1914. For many months he was at the Doeberitz Camp, from which he, and his friend Kirkaldy, escaped. They got into Hanover but were recaptured and brought back to Doeberitz where they were given "Cells and bread and water." Since then he has been in many camps and working groups, has suffered untold hardships and privations, was in the awful reprisal camp in Courland (Ekau) where the Germans made our men work in the trenches under Russian fire. They worked and marched 19 hours a day and had one ration served out to them in 24 hours—a hunk of black bread and a bowl of watery soup. The letters, food, and clothing parcels sent from England were withheld, and no letters were allowed to be sent home. Several died there, many more collapsed from starvation and exhaustion and all suffered from frost-bitten hands and feet.

Farrant is now at Chemnitz Camp, in Saxony, and is having much more humane treatment. He writes that he is well and we gather from his letters that after nearly four years of inhuman German treatment his spirits are unbroken. We now have hopes that he may be one of the repatriated prisoners, concerning whom negotiations are going forward at the present time at the Hague. His present address is J. C. Farrant, 3228 Royal Naval Division, 7, Kompagnie, No. 121, Chemnitz, Saxony.

A unique item in connection with J. C. Farrant's service is that the London office of the Hardinge Conical Mill Co., of which he was Manager, was likely to be closed as the men had been called up early in 1916, when Mr. H. W. Hardinge determined to keep the place open for Mr. Farrant on his return, and to that end offered the post of acting Manager to Mr. Farrant's mother—a lady who had no technical or business knowledge but who was interested in her son's work and very keen to do something to help.

Otto A. Friedlander has been in active service since 1914, in England, Egypt, Gallipoli, and France; he is now stationed in India and is expected to leave to take an appointment in the Persian Gulf.

A. H. Wethey advised recently that he was working in France with the Fund for War Devastated Villages. Their work of assisting some of the villagers in the Somme devastated district had been rudely interrupted by the Boches. Their delegates had to flee with the poor refugees. Meantime they are helping such of the refugees as they can and preparing greater assistance when the poor people are once again restored to their homes.

MEMBERS OF THE INSTITUTE IN MILITARY SERVICE

ANDERSON, ALEXANDER, Captain, Royal Garrison Artillery.

ANDERSON, GEORGE K., JR., Lieutenant, 30th Co., 3d Replacement Regiment.

ARMSTEAD, H. H., Captain, Quartermaster Corps, U. S. N. A.

ARMSTRONG, HAROLD KERR, Student Flight Officer, U. S. Naval Reserve Flying Corps, Dunwoody Naval Training Station, Minneapolis, Minn.

BAKER, HARRY A., Captain, Co. M, 53d Pioneer Infantry.

BASSETT, THOMAS E., Corporal, 340th Field Artillery, Battery A, 89th Division, A. E. F.

BATES, WM. T., 3d Reserve Officers' Training Camp.

BAUMGARTEN, K., 1st Lieutenant, 1st Corps School A. P. O. 703.

BAYLESS, G. E. S., Supply Dept., U. S. Submarine Base, New London, Conn.

BENSEL, J. A., Major, U. S. R., Board of Control, War Construction Activities, Norfolk, Va.

BILLICK, DON C., Co. C, Ordnance Supply School.

BILLINGSLEY, PAUL, 1st Lieutenant, National Army, Statistics Branch, General Staff.

BLANDY, S. H. B., B. E. F.

BRENNEN, GEORGE K., Naval Air Service.

BROKAW, ALBERT DUDLEY, Petroleum Expert, U. S. Shipping Board, Washington, D. C.

BROOKS, C. A., Recruit Detachment, 27th Engineers, Camp Meade, Md.

BROWN, LOWELL H., Captain, Signal Reserve Corps, Aviation Section, War Dept., Spruce Production Div., South Beach, Ore.

BRUNEL, LOUIS J., Lieutenant, American Forces, France.

CADMAN, JOHN, Director of the Petroleum Executive and Chairman of the Inter-Allied Petroleum Conference.

CALDWELL, FOREST B., In service of Government, stimulating the production of chrome ore.

CHALMERS, THOMAS S., Major, Ordnance, N. A.

CHAPMAN, ROBERT H., Major, Engineer Reserve Corps.

CHASE, J. L., Engineers' Training Depot, St. Johns, Que., Canada.

CHETNEY, P. C., Lieutenant, 15th Battalion, Headquarters Co., F. A. R. D.

CLAUSEN, E. H., Captain, General Engineer Depot, 1438 You St., Washington, D. C.

COHEN, JULIUS M., Captain, 319th Engineers.

COPELAND, F. W., 2d Lieutenant, 333d Heavy Artillery, U. S. A.

CROWE, JOHN J., Physical Met., Hull Div., Philadelphia Navy Yard.

CURRAN, FRANCIS R., 4th Engineer Officers' Training Camp, Camp Lee, Va.

DARRINGTON, PAUL N., 1st Lieutenant, 46th U. S. Infantry, Camp Sheridan, Montgomery, Ala.

DAVIS, ANGUS W., Lieut.-Col., Canadian Engineers Tunnelling Depot, Seaford, Eng.

DEVEREUX, WILLIAM G., Major, 144th Field Artillery.

DONDERO, F. N., Private, Co. F, 316th Engineers, A. E. F.

- DRAKE, M. C., 2d Lieutenant, Headquarters Co., 325th Inf., A. E. F.
DUDLEY, H. C., Co. B, 36th Engineers, A. E. F.
DWYER, C. EUSTACE, 1st Lieutenant, Ordnance Reserve Corps, Edgewood Arsenal, Edgewood, Md.
EATON, LUCIEN, Captain, Engineer Officers, Reserve Corps.
EDMONDSON, H. W., Captain, Engineer Reserve Corps, 28th Engineers.
ELLIS, ERNEST W., 2d Lieutenant, School of Fire, F. A.
ERIC, A., U. S. Explosives Plant, 16 East 42d St., New York, N. Y.
FELL, HAROLD B, Field Artillery, Replacement Depot, Camp Jackson, S. C.
GIBB, ALLAN, Captain, Royal Engineers, F. E. XXII Corps, B. E. F.
GREEN, WALDRON A., Co. C, 27th Engineers.
HALL, DURAND APPLETON, U. S. Shipping, Board, Washington, D. C.
HAMMON, W. C., 1st Lieutenant, 4th Engineers, France.
HAZARD, ARCHIE M., Co. A, 604th Engineers.
HEILMAN, J. C., 4th Co., 166th Depot Brigade.
HILBY, GEORGE R., Lieutenant, A. S., Sig. R. C.
HOFECKER, CHARLES A., Wounded in Battle of Verdun in 1914.
HOLLISTER, SCOVILL E., Recruit Detachment, 311th Aero Squadron, March Field, Riverside, Cal.
HOLMQUIST, GUSTAVE S., Ordnance Dept., Washington, D. C.
HOSFORD, H. W., Lieutenant, Navy Dept., Washington, D. C.
HOTCHKIN, HARRY, 1st Lieutenant, 539th Engineers, N. A.
JOHNSTON, JOHN, Sec'y, National Research Council.
KAMP, W. H., 2d Lieutenant, 57th Aero Squadron, A. E. F.
KIRKPATRICK, G. H., Lieut.-Col., 11th Canadian Mounted Rifles, France.
KITSON, H. W., Ensign, U. S. N. R. F., Naval Acad., Annapolis, Md.
LONDON, ROBERT R., 1st Lieutenant, Signal Officers' Reserve Corps, A. E. F.
LASKY, BERNARD H., Master Engr., Headquarters Co., 316th Engineers.
LINCH, HARRY A., 1st Lieutenant, 345th Field Artillery, N. A., A. E. F.
LINDBURY, CARL O., War Minerals Investigator, Bureau of Mines.
LINDSLEY, NORMAN D., 1st Lieutenant, Co. E, 318th Engineers, A. E. F.
LIVINGSTON, ARCHIBALD R., Major, 115th Engineers.
McCUTCHEON, KENNETH C., 1st Lieutenant, 4th Co., Coast Artillery.
McLAUGHLIN, WARNER, 1st Lieutenant, Ordnance Reserve Corps, Inspection Division.
MACISAAC, DONALD, Lieutenant, 11th Engineers, Co. B (Railway), A. E. F.
MACMILLAN, HERBERT, 1st Lieutenant, C. A. C.
MARKLE, DONALD, Captain, 4th Division Ammunition Train, A. E. F.
MAXWELL, NORMAN E., Co. 4, E. R. O. T. C.
MELITZER, SAMUEL, 2d Lieutenant, Engineers, N. A., Quarters No. 14, Washington Barracks, Washington, D. C.
METZ, GILBERT F., Ensign, U. S. N. R. F.
MEWHIRTER, SYDNEY A., Lieutenant, Co. D, 314th Engineers, 89th Division, A. E. F.
MITCHELL, LEROY B., Lieutenant, 65th Engineers.
MOLL, C. D., Camp Wheeler, Macon, Ga.
MORGAN, GEORGE DODD, Co. B, Camouflage Section, 49th Engineers, A. E. F.

NESBIT, MILLARD F., 4th E. R. O. T. C.

NOBLE, CLARKE O., 2d Lieutenant, 638th Aero Squadron, U. S. Air Service, London.

NORCROSS, F. S., JR., Captain, 27th Engineers.

NOTT, T. E., School of Military Aeronautics, Cornell University, Ithaca, N. Y.

NOWLAN, Harry H., 1st Lieutenant, 20th Field Artillery, A. E. F.

PAGE, E. R., 1st Lieutenant, Aviation Section, Signal Reserve Corps.

PATTERSON, S. B., JR., 1st Lieutenant, Co. 1, Engineer Officers' Training Camp.

PEABODY, FRANCIS S., Chief, Explosive Section, Bureau of Mines.

PEARSON, ALFRED, JR., Captain, Engineer Reserve Corps, U. S. A.

PERRY, O. B., Lieut.-Col., Headquarters, 27th Engineers.

PETZEL, CHARLES L., Corporal, Co. B, 302d Field Signal Battalion, A. E. F.

PHILLIPS, D. McN., Lieutenant, A. S., Sig. R. C., Commanding Officer, 69th Aero Squadron.

PIPKIN, PHILIP H., 1st Lieutenant, Engineer Reserve Corps, 116th Engineers, A. P. O. No. 733, A. E. F.

POWELL, D. A., Candidate, 1st Training Co., 5th Training Camp, C. A. C.

PRATT, JOSEPH HYDE, Lieut.-Col., 105th Engineers, 30th Division, A. E. F.

PROBERT, FRANK H., War Minerals Investigator, Bureau of Mines.

REED, MAURICE J., 2d Lieutenant, Signal Reserve Corps, A. S., Unattached, A. E. F.

RICKARD, EDGAR, Food Administration.

ROBERTS, DUDLEY E., Sgt., Ordnance Reserve Corps, Engr. of Tests, Symington Machine Corpn., Rochester, N. Y.

ROBBINS, H. R., Captain, National Army, General Staff, Washington, D. C.

ROCKWELL, F. G., Captain, 305th Engineers.

RUKEYSER, WALTER A., Naval Flying Corps.

RYPINSKI, J. E., U. S. Marine Corps Reserve, Overseas Depot, Quantico, Va.

SAEGER, C. MARSHALL, JR., Junior Chem., Chem. Met. Dept., Bureau of Standards, Washington, D. C.

SCHABER, CARL F., Lieutenant, U. S. R., 37th Infantry.

SEARLS, FRED, JR., 1st Lieutenant, Engineers, A. E. F.

SHAW, JOSEPH S., Inspector of Construction, U. S. Ordnance Dept.

SHURICK, A. T., Captain, E. R. C., Co. A, 1st Replacement Engineers.

SMALL, H. L., Captain, 5th Heavy Mobile Ordnance Repair Shop, Ordnance Training Camp, Camp Hancock.

SMITH, JAMES H., JR., Captain, Co. B, 304th Engineers.

SMYTH, JOHN G., Captain, O. R. C., Production Div.

STACK, F. L., Ordnance Supply School, Camp Hancock, Ga.

STADER, JAMES A., Captain, Field Artillery, O. R. C., P. O. No. 718, A. E. F.

STEPHENSON, F. L., U. S. Naval Aviation Detachment, Mass. Inst. of Tech., Cambridge, Mass.

STEWART, M. B., Battery, 4th O. T. C.

STOCKETT, N. A., 2d Lieutenant, N. A., Co. D, 306th Engineers.

SULLY, KENNETH M., Sgt., Co. F, 604th Engineers.

SWEET, A. T., Lieutenant, 107th U. S. Engineers, Headquarters Co., A. E. F.

TINSLEY, ROBERT B., Captain, Co. A, 605th Engineers.

TYSSOWSKI, JOHN, Major, Quartermaster Corps, New York General Supply Depot, in charge of the Subsistence Division.

VRANG, CHRISTION, Private, First Class Signal Enlisted Reserve Corps, Aviation Section, Stanford Univ., Cal.

WARD, HARRY J., 1st Lieutenant, Aviation Section, Signal Reserve Corps.

WEIMER, RAYMOND S., Co. 6, Engineer Officers' Training Camp.

WILLIAMS, RALPH O., Lieutenant, Co. F, 319th Infantry, A. E. F.

WISSER, EDWARD HOLLISTER, 2d Lieutenant, Engineer Reserve Corps, U. S. A.

WRAITH, C. R., Captain, Engineer Reserve Corps.

WRIGHT, HARRY F., Lieutenant, Co. B, Second Regiment, Oklahoma Guards.

WRIGHT, WILLIAM H., Captain, Engineer Reserve Corps, General Engineering Depot, Washington, D. C.

YOUNG, FRED W., 2d Lieutenant, Aviation Section, Signal Corps, A. E. F.

WAR ACTIVITIES OF THE ENGINEERS

GOVERNMENT ESTABLISHES DIVISION OF ENGINEERING

Government supervision of employment for technical men has been inaugurated by the United States Employment Service, through the establishment of a Division of Engineering, with A. H. Krom, of Chicago, formerly Secretary of the American Association of Engineers, as Director.

War demands on the engineering profession have already caused a serious shortage of men with mechanical designing experience and those with practical experience in chemical engineering. At present the professional organizing mediums reach less than 20 per cent. of the estimated 300,000 technical men in the country. This is not a satisfactory arrangement for war times. All the technical men of the country must be reached and, in addition, all men with technical experience must be carefully registered so that they will be immediately available. The advantages of such a governmental registering and systematizing of employment will be apparent at once, to the engineer.

Considering that this is principally an engineer's war, the importance of Federal direction of distribution and conservation of the technical service of the country is apparent. The Service will be started through the office of the Director of Engineering, 29 S. LaSalle St., Chicago. All technical men desiring to register for emergency Government work or permanent advancement in positions meeting their qualifications, are urged to volunteer at once for registration, classification and employment.

WAR ACTIVITIES OF THE NATIONAL RESEARCH COUNCIL

By George Ellery Hale, *Chairman*

(Extracts from an address delivered under the auspices of the Engineering Foundation, New York, May 28, 1918)

It is already a trite saying that this is a war of engineering and science. Yet it is a question whether the average person, or indeed whether even the technically qualified man whose work has been concentrated

in a particular field, can realize in how large a sense these words are true. To do so he must survey the vast engineering achievements of the Entente and of the Central Powers, and appreciate what countless details they involve and how far their ramifications extend into apparently unrelated fields.

In the vast field of engineering, both military and industrial, the national engineering societies have played a truly national part. Merely to enumerate their contributions, in men and in activities of the most varied description, would occupy the entire time at my disposal. I must therefore confine myself to the barest mention of some of the most conspicuous of these activities: of the prominent part they have played in the work of the Naval Consulting Board, which has contributed in so many important ways to our progress in the war; of the gallantry of their members on the western front, where they have proved that the engineer can fight no less effectively than he can build; of the countless products, in munitions of war, and other necessities of national defense; of the factories they operate; of the railways, docks, cantonments, and fortifications they have erected, here and in France; of the ships they have sped down the ways to overcome the submarine.

The National Research Council, of whose work I have been requested to speak, has special reasons for gratitude to the engineers of the national societies. Two years ago, when its organization had just been undertaken, the Research Council was without funds. The Engineering Foundation, established by these societies on Mr. Swasey's endowment for the promotion of research, saw and appreciated the advantage of creating a body for the federation of research agencies, governmental, educational, separately endowed, and industrial. It accordingly placed its entire resources at the disposal of the Research Council, gave it the services of its Secretary, and provided an office for the Council's work. Special contributions from Mr. Ambrose Swasey and Mr. Edward D. Adams enlarged the income available for this purpose, and thus the work of the Research Council was inaugurated. Today, when ample funds from other sources have eliminated financial difficulties, the Research Council does not forget the indispensable aid it received from the Engineering Foundation at the most critical period in its existence.

(Mr. Hale next mentioned the development of science and engineering during the Civil War, leading to the organization of the National Academy of Sciences in 1863. He alluded, also, to the recognition of science as a weapon by Napoleon, during his campaign in Egypt.—Ed.)

The activities of the National Academy of Sciences during the Civil War, as well as the provisions of its charter, indicated its fitness for renewed service in support of the national defense. In April, 1916, when the attack on the "Sussex" had greatly increased the tension of our relations with Germany, the Academy received from the President a call for immediate action. He expressed the desire that the Academy should bring into coöperation governmental, educational, industrial, and other research agencies, primarily in the interest of the national defense, but with full recognition of the duties that must be performed in the furtherance of scientific and industrial progress.

The National Research Council, comprising the chiefs of the technical bureaus of the Army and Navy, the heads of Government bureaus engaged in scientific research, a group of investigators representing educational institutions and research foundations, and another group

including representatives of industrial and engineering research, was accordingly constituted by the Academy, with the active coöperation of the leading national scientific and engineering societies.

On February 28, 1917, the Council of National Defense passed a resolution expressing its recognition of the fact that the National Research Council, at the request of the President, had organized the scientific resources of the country in the interest of national defense and national welfare, and requesting the Research Council to coöperate with it in such matters. The Chairman of the Council thereupon opened offices in the Munsey Building in March, and entered into active coöperation with the Council of National Defense, which was then established in the same building.

Soon afterward the Research Council was requested to act as the Department of Science and Research of the Council of National Defense. A further extension of its duties occurred in July, when it was requested by the Chief Signal Officer to organize the Division of Science and Research of the Signal Corps. Another important request by Assistant Secretary of War Stettinius resulted in the appointment of a Committee of the Research Council to organize and direct researches for the improvement of processes for the fixation of nitrogen, undertaken in coöperation with the Ordnance Department of the Army.

The war organization of the Council involves the grouping of its various committees under a series of Divisions, each of which deals with related subjects. Thus the Physics Division comprises the work of committees of physicists, mathematicians, astronomers, and geophysicists. This division works in very close coöperation with the Engineering Division, in view of the impossibility of distinguishing sharply between the problems belonging in their respective fields. Under the Engineering Division, which represents the expansion of the work of our former Engineering Committee, due to the rapidly increasing demands upon the Council from Government bureaus and other sources, there are sections or committees dealing with mechanical engineering, electrical engineering, metallurgy, and with various special fields of research. The National Advisory Committee for Aeronautics acts as the Aeronautics Section of the Engineering Division. Permit me to express here the appreciation of the National Research Council of the action of the Engineering Foundation and the national engineering societies, which have appointed representatives to serve as members of the Executive Committee of the Engineering Division. We have been fortunate enough to secure the services of Dr. Henry M. Howe as Chairman of this Division, while the Chairmanships of the Sections of Electrical Engineering, Mechanical Engineering, and Metallurgy, are held by Professor Comfort A. Adams, Mr. S. L. G. Knox, and Professor Bradley Stoughton, respectively. Lieutenant-Colonel Robert A. Millikan, who also heads the Division of Science and Research of the Signal Corps, is Chairman of the Physics Division.

Within the extensive field covered by these two Divisions, numerous problems are constantly presenting themselves. Take such a subject as naval range finders. Here we are dealing with an optical instrument of precision, involving methods employed by the physicist and by the astronomer concerned with the measurement of stellar parallaxes. As existing range finders are marked by several defects, a well known physicist, who has had extensive experience in the development of new types of instruments, was requested to attack the problem. He has already

constructed a new range finder which seems to offer important advantages.

Another problem in physics is the location of enemy guns by sound. As M. Painlevé has stated publicly that apparatus devised by the French physicists for this purpose has been captured by the Germans, there can be no harm in referring to it. Here it is a question of determining the exact time of arrival of the sound wave emitted by the discharge of an enemy gun at three or more points where automatic recording instruments are located. The research problem involved is therefore the development of simple and effective recording instruments, and a rapid method of calculation which will permit the observations to be reduced and the position of the enemy gun located in the shortest possible space of time. The National Research Council initiated the sound-ranging service of the Army under the Signal Corps (it was subsequently transferred to the Engineer Corps), and secured the development of new forms of recording apparatus.* Major Augustus Trowbridge of Princeton, who is in charge of the service in France, is a well known physicist. The quickest method hitherto devised for reducing the observations is due to an equally well known Princeton astronomer, who is working under the auspices of the National Research Council.

Another field in which the experience of the astronomer in computing orbits is directly applicable is that connected with the dropping of bombs from aircraft and the calculation of the trajectories of projectiles. Here several physicists and astronomers have obtained new and interesting results, useful in military practice. Many submarine problems, the location of invisible aircraft, various questions connected with wireless communication, the visibility of objects on land and sea, and scores of other questions falling within the fields of acoustics, optics, electricity and other branches of physics, afford abundant opportunity for researches of the most varied character. Also lying within the field of the Physics Division is the work of the Committee on Navigation and Nautical Instruments, under the Chairmanship of Dr. L. A. Bauer, which has aided the Shipping Board in the selection and testing of compasses, chronometers, and other nautical instruments.

The Engineering Division has dealt with such problems as the design of two new types of gun, for one of which the Ordnance Department of the Army has made a special appropriation. It is making an extensive study, in coöperation with the Ordnance Bureau of the Navy, of the entire problem of gun-pointing, which involves a great variety of interesting questions and the coöperation of men who have derived the necessary experience from their work in engineering, physics, and other branches of science. Another very interesting investigation conducted under the auspices of the Engineering Division has dealt with the best composition and design of helmets and protective body armor for troops. Dr. Bashford Dean, Chairman of this special Committee, and now a major in the Ordnance Department of the Army, is Curator of Arms and Armor at the Metropolitan Museum of Art.

Passing to the important Division of Chemistry and Chemical Technology, organized by Professor (now Lieutenant-Colonel) Marston

* Captain Ernest Weibel, who took part at the Bureau of Standards in developing a new recording instrument, was killed at the front in France while applying the method.

T. Bogert, and now under the Chairmanship of Dr. John Johnston, we enter a field of the first importance from a military and industrial standpoint. It is impossible here even to touch upon the extensive work of this Division, which includes 34 committees dealing with various phases of chemistry. Perhaps the most important work undertaken by the Division is the exhaustive study of processes for nitrogen fixation, conducted under its auspices. The first committee appointed by the National Research Council in May, 1916, at the request of the Secretary of War, was charged with the duty of advising the Ordnance Department of the Army regarding the best processes to be adopted in its great nitrate plants. Dr. Arthur A. Noyes, Chairman of this Committee, is also Chairman of a new Committee, recently appointed by the Research Council at the request of Assistant Secretary of War Stettinius, to survey the researches now in progress for the improvement of these processes, to plan further investigations relating to nitrogen-fixation, to arrange for the active prosecution of such investigations, and to exercise close oversight over their progress. Working in coöperation with the officers of the Ordnance Department, this Committee has initiated various researches for the purpose of improving existing processes, one of which has proved so successful that it will materially reduce the cost of nitrogen fixation.

It should be said here, once for all, that the policy of the National Research Council is now, and has been from the outset, invariably to recommend the immediate adoption and utilization for military and naval purposes of the best devices or methods known at the time, with the understanding that research for the purpose of improving such devices should not retard production demanded to meet pressing military needs.

A word should be said regarding the Division of Geology and Geography, under the Chairmanship of Dr. John C. Merriam, which includes Committees on both of these subjects. Important work on road materials has been done under the supervision of the late Dr. William Bullock Clark, as a part of the work of the Geology Committee (Dr. John M. Clarke, Chairman). This Division is working in close coöperation with the Army War College, and has sent a geologist abroad to report on the best services of geologists in connection with the war. A valuable "Handbook of Northern France," prepared by Dr. William M. Davis, Chairman of the Geography Committee, has been widely circulated among American officers. The general information thus supplied is being supplemented by lectures on military geography, given in the various cantonments. In this connection special mention should be made of an important work prepared by Major Douglas W. Johnson, a member of the Geography Committee now in France, entitled "Topography and Strategy in the War."

The Division of Medicine and the Related Sciences, under the Chairmanship of Dr. R. M. Pearce, includes Committees on Anatomy, Physiology, Psychology, Anthropology, Medical Zoology, Toxicity of Preserved Foods, Psychiatry, and other special subjects, and is one of the most active Divisions of the Research Council. Aided by an appropriation of \$50,000 from the Rockefeller Foundation, and working in the closest coöperation with the Surgeon General of the Army (through Colonel Russell) and of the Navy (through Dr. Stitt), it has organized many researches of direct military value, assisted the Surgeons General

of the Army and Navy in procuring trained investigators to enter the respective services, and initiated many other activities of importance. It is impossible within present limits to describe the numerous medical researches undertaken; about half of them are in the field of physiology alone, and deal with problems of shock, control of hemorrhage and similar subjects. The remaining half are divided, roughly between problems concerning the acute infectious diseases, the control of vermin, food problems, and the diseases of munition workers.

A word should be said regarding the novel and important work in psychology, due to the initiative of Major Robert M. Yerkes, Chairman of the Psychology Committee of the Research Council. Perceiving the possibility of psychological examination as applied to the Army, and with the active aid of a strong committee, Dr. Yerkes prepared a scheme of psychological examination, and secured permission to test it with troops. Meanwhile a plan for applying tests on a large scale had been prepared and presented to the Surgeon General through the National Research Council. The preliminary tests impressed military officers so favorably that a new Division of the Surgeon General's Office was created, and Dr. Yerkes was commissioned a major in charge of the work. The psychological tests are now being applied to all troops in the Army, and the intellectual rating thus afforded has proved to be very useful in practice. This is one of the most interesting scientific innovations of the war.

As the functions of the Committee on Anthropology in connection with military needs might not be grasped without reflection, it should be remarked that this Committee, then under the Chairmanship of Dr. William H. Holmes, was the first to point out that under the former height limit of enlistment (5 ft. 4 in.) the taller native American would be discriminated against when compared with the shorter immigrants from many European nations. The figures presented by the Committee convinced the War Department, and the height limit was accordingly reduced to 5 ft., in accordance with the recommendations of the Committee.

The field covered by the Division of Agriculture, Botany, Zoology, Forestry and Fisheries, under the Chairmanship of Dr. Vernon Kellogg, is a wide one, of fundamental importance in connection with the war. Working in close coöperation with the Department of Agriculture, the Bureau of Forestry and Fisheries, and the Food Administration, this Division is accomplishing much valuable work. The Agriculture Committee has initiated several large investigations involving the coöperation of members of the Department of Agriculture, State Experiment Stations, and investigators in the universities. The last piece of work organized by the Division was undertaken at the request of the Food Administration, which requested the Research Council to appoint a committee to investigate binder-twine fibers, with special reference to sisal and its substitutes.

At the outbreak of the war the average statesman of the Allied powers was but little concerned with the interests of research. Necessity, however, soon opened his eyes. He began to perceive the enormous advantages derived by Germany from the utilization of science, and sought to offset them by the creation of appropriate agencies. Thus arose throughout the British Empire a group of Councils for Scientific and Industrial Research. Without entering here into a detailed discussion of these Councils, we may mention certain typical illustrations of their

activities from the report of the British Advisory Council for Scientific and Industrial Research for the year 1916-17.

The British Advisory Council has devoted itself during the year mainly to the organization of industrial research, partly because of the prime importance of stimulating and fixing the interest of manufacture in the development of industry through research, and partly because the effect of the war has been to render industrial leaders more susceptible than ever before to the growth of new ideas. In pure science, on the contrary, the war has seriously affected the prosecution of research, because so many investigators have been drawn into military and industrial activities. Thus, while the Advisory Council strongly emphasizes the fundamental importance of pure science, it has been forced to postpone its activities in this field until the arrival of more favorable conditions.

Research for the development of the industries may be conducted in several different ways. In this country a stimulating example has been set by such great corporations as the American Telephone and Telegraph Company, the General Electric Company, the Eastman Kodak Company, and the Westinghouse Company, all of which have established large research laboratories. The value of this example has been enhanced by the remarkable success achieved by these laboratories in matters affecting public welfare, such as the reduction in cost of electric lighting caused by the development of the Mazda lamp and the possibility of transcontinental telephony, not to mention the latest advances in the field of wireless telephony.

The National Research Council, joining with its valued ally and supporter, the Engineering Foundation, is just entering upon an extensive campaign for the promotion of industrial research. In addition to a strong active committee, comprising the heads of leading industrial research laboratories and others prominently identified with scientific methods of developing American industries, an Advisory Committee has been formed to back the movement.

Science is in the air, keen competition is in prospect, and the industries are more favorably inclined than ever before to the widespread use of research methods. Their greatest leaders, moreover, are unanimous in their appreciation of the necessity of promoting research for the sake of advancing knowledge, as well as for immediate commercial advantage. Only thus can the most fundamental and unexpected advances be rendered possible, and continued progress in all directions assured.

DEVELOPMENT OF ENGINEERING AND INDUSTRIAL RESEARCH

A joint meeting of the committees of the National Research Council and of the Engineering Foundation for formulating a scheme for developing engineering and industrial research was held on May 20, 1918, in the Board Room of the American Institute of Mining Engineers. Present: Colonel John J. Carty, Chairman, Gano Dunn, George E. Hale, Lieutenant-Colonel Robert A. Millikan, John Johnston, of the Committee of the National Research Council; Michael I. Pupin, Chairman, and Edward D. Adams, of the Committee of Engineering Foundation; also Walter Rautenstrauch, by invitation, and Alfred D. Flinn, Secretary of Engineering Foundation, who acted as secretary of the meeting. Dr. Pupin acted as chairman.

There were submitted copies of President Wilson's Executive Order of May 11, 1918, perpetuating the National Research Council and defining its duties. Colonel Carty, as Chairman of the Council's committee, made a general statement of the purpose and plans of the National Research Council concerning industrial research and suggested two or three ways in which Engineering Foundation might join with the Council in this important work.

After lengthy discussion of the general project and a number of its details, it was unanimously

VOTED: that the committees of the National Research Council and the Engineering Foundation recommend to the National Research Council that the Industrial Research Section of the National Research Council shall consist at first of 12 members, subject to enlargement later, if found desirable, without limiting the nominations to specific numbers from any organization; that the terms for members of this Section be three years each, with provision for rotation in office so as to bring in new men from time to time and with such arrangement of the expiration of terms as to provide for a change of about one-third of the membership at a time.

In accordance with this vote the following persons were selected as nominees for members of the section: Willis R. Whitney, of the General Electric Co.; C. E. K. Mees, of Eastman Kodak Co.; Walter Rautenstrauch, of Columbia University; Leo H. Baekeland, of Naval Consulting Board; a representative of the Bureau of Standards, to be selected by its Director; a representative of the Bureau of Mines, to be selected by its Director; the Secretary of the National Research Council, and the Secretary of the Engineering Foundation, it being understood that these eight, after careful review of the field, should nominate the remaining four members of the section, with a few alternates.

It was the consensus of opinion that Labor should have one or more suitable members on the Section, who should take part in the work of the Section from its inception.

VOTED: that the names thus selected by the two committees be transmitted to the National Research Council as the recommendations of the committees jointly.

VOTED: that these committees in joint meeting recommend to the National Research Council and the Engineering Foundation Board that the Chairmen of the Council and of the Foundation be authorized jointly to name a committee to nominate men to fill vacancies, resulting from the expiration of terms or other causes in the Industrial Research Section of the National Research Council, the appointments to be made by the National Research Council.

ENGINEERING COUNCIL SEEKS COMMITTEE HELPERS

Engineering Council, as was designed, is engaging in numerous activities for the engineering profession of America, many of these activities being directly or indirectly connected with the war. The Council is a body of representatives from member societies conducting most of its work through committees. For effectiveness these committees have usually a small number of members, although committee membership is not limited to the representatives on Engineering Council. Men have been selected for committee membership because of broad knowledge and extended experience in the field assigned to the committee.

As the work of some committee develops, however, there are occasions when helpers are needed who can devote time to details, to special investigations, to getting local information in some community or state, to compiling and analyzing information already accumulated, or to scouting

for men needed for some particular service. When need arises for such assistance it is often difficult to think of or to find the right man available at that moment. In order to meet this difficulty, to give a larger number of engineers a share in the activities, to broaden Council's contact and gain greater breadth for its views and statements, as well as to make its work more widely known, Engineering Council is requesting engineers who can help, to write to Council's office registering their names and addresses, and in a general way stating the extent and nature of service each one is willing to render. This is an opportunity for some of the younger members of the profession to take a hand in society activities, but the request is not limited to the men of few years. Of course, every one registered may not be called upon, or it may be a long time, seemingly, before a volunteer is asked for help. On the other hand, calls may come promptly and frequently and opportunities may be afforded for services of no small value to the profession and the public.

To indicate a few lines of Engineering Council's work, the following brief statements are given about some of the committees.

The Public Affairs Committee reports on matters of public policy, and those relating to national, state or local government, other than technical questions. One question of active interest now before this committee, for example, is that of licensing engineers.

The American Engineering Service has the duty of compiling as complete a classified catalogue of the engineers of America as it may be practicable to get together. Much information has been assembled but a great deal remains to be collected. This committee frequently could use volunteers, not only in New York but in distant communities, in scouting for men to meet special and urgent calls from the Government.

The War Committee of Technical Societies is engaged upon the examination of new inventions offered to the War and Navy Departments, and to stimulation of the development of useful new appliances for warfare. In reviewing ideas received, preparing bulletins and writing reports and records, this committee could make use of a number of helpers from time to time.

The Water Conservation Committee is organizing to deal with questions of policy in various parts of the country concerning the utilization and control of water for such purposes as power development, navigation, irrigation and municipal supply. This committee will need correspondents to aid it in keeping informed or in making special investigations about local laws and policies.

Engineers who are able and willing to take some part in this service for the profession should communicate with Alfred D. Flinn, Secretary of Engineering Council, 29 West 39th Street, New York.

ENGINEER RESERVE CORPS NEEDS 2000 OFFICERS

Approximately 2000 engineer officers are required immediately for the Army, and, to obtain them with a minimum of delay, a board of examining officers will be sent from Washington for the purpose of visiting many of the principal cities of the United States to examine members of the engineering profession who may desire to serve their country in the present emergency.

The Examining Board will only receive applications for appointment in the grades of first lieutenant and captain, and only those applicants meeting the following requirements will be considered:

Age Limits.—For the grade of first lieutenant, 32 to 36 years; for captain, 36 to 42 years. These limits may be slightly increased or decreased in special cases, except that no one who is within the draft age will be considered. Applicants must be engaged in the active practice of the engineering profession, and be in good physical condition.

Professional Qualifications and Experience.—No set rules have been established. An applicant's fitness for commission will be determined by the Examining Board. All applicants must be citizens of the United States. No application will be received from anyone now in Government Service. Applications will not be considered from anyone born in a country with which the United States is at war, or born in a country allied with a country with which the United States is at war, even though he be a naturalized citizen of this country.

All applicants accepted by the Examining Board will be commissioned within ten days or two weeks, and within a few days thereafter will receive orders to report at an Engineer Officers' Training Camp, either at Camp Lee, Petersburg, Va., or at Camp Humphreys, Va., near Washington, where they will be given a course in military training previous to being assigned to duty with engineer troops.

Applicants must understand, however, that it is required of an engineer officer that he not only be professionally qualified, but must also possess the requisite qualities of leadership and temperament to fit him for the command of troops.

The Government will allow traveling expenses at the rate of 7 c. per mile to applicants who may be commissioned, and they receive, while in the training camp, the regular pay of an officer of their rank.

Members of the Institute who desire to apply for these commissions in the Engineer Reserve Corps, and who are able in every way to meet the specifications indicated above, are requested to notify the Secretary at once. Qualified applicants will thereupon receive official application and experience blanks, together with proper instructions.

FOR INFORMATION REGARDING WAR ACTIVITIES

Owing to the enormous increase of Government war work, the governmental departments at Washington are being flooded with letters of inquiry on every conceivable subject concerning the war, and it has been found a physical impossibility for the clerks, though they number an army in themselves now, to give many of these letters proper attention and reply. There is published a daily at Washington, under authority of and by direction of the President, a Government newspaper—The Official U. S. Bulletin. This newspaper prints every day all the more important rulings, decisions, regulations, proclamations, orders, etc. as they are promulgated by the several departments and the many special committees and agencies now in operation at the National Capital. This official journal is posted daily in every postoffice in the United States, more than 56,000 in number, and may also be found on file at all libraries, boards of trade and chambers of commerce, the offices of mayors, governors, and Federal officials. By consulting these files, most questions will be found readily answered; there will be little necessity for letter writing; the unnecessary congestion of the mails will be appreciably relieved; the railroads will be called upon to move fewer correspondence sacks, and the

mass of business that is piling up in the Government departments will be eased considerably. Hundreds of clerks, now answering correspondence, will be enabled to give their time to essentially important work, and a fundamentally patriotic service will have been performed by the public.

MEN NEEDED ON SUBMARINES

It is desired to call the attention of young men who have had technical training and experience to the fact that their abilities can best be put at the service of the country by selecting a branch of service in which their special qualifications will be of the greatest use.

The submarine force of the United States Navy requires the services, as officers on board submarines, of young men who have had technical training in mechanical and electrical engineering and who have had experience in these professions. It is intended to enroll a number of such men as provisional ensigns in the Naval Reserve Force, give them a course of instruction in deck duties at Annapolis and a course in submarine work at New London. Those who successfully pass these courses will then be sent on board submarines for regular duty.

It is requested that any men who desire this duty and who are qualified as below outlined send their names and addresses to the Commander Submarine Force, *U. S. S. Chicago*, care of Postmaster, New York.

Qualifications required:

Desire to serve in submarines.

Degree of M. E., E. E., or E. M.

Two and one-half years' practical experience in profession.

Not over 35 years old.

Physically strong and sound.

Candidates should, if practicable, receive the indorsement of one of the following organizations:

Naval Consulting Board.

National Research Council.

American Society of Mechanical Engineers.

American Institute of Electrical Engineers.

American Institute of Mining Engineers.

CONANT TAYLOR, *Lieutenant-Commander, U. S. Navy.*

BRITISH AND AMERICAN FRIENDSHIP

By Sir Robert Hadfield

I am asked to contribute a few words to "The Book of British and American Friendship." This book of the two countries ought never to have been closed. It was a colossal mistake on the part of certain of our statesmen in the past which led to the severing of the interests of the two countries which, by the greatest of all bonds—Nature—were meant to be one. However, that is past, and a new book is opened, one full of promise for the world's future.

I should imagine that outside the Kaiser-Junker classes, even the Hun himself would prefer to be under Anglo-Saxon laws and customs rather than his own. At any rate, judging from the number of Huns who have

flocked to the United States and to the outlying districts of the British Empire, they found something in those parts of the world which do not exist in the Fatherland.

It is now some thirty years since I paid my first visit to the wonderful land over the seas—the United States of America. It was to me a great surprise to find that there could be any one in either that country or my own who imagined we were not meant to pull together in this world. Late events have shown this in a still more striking manner. If we do not work hand in hand, Justice and Liberty will, alas, have a sorry time in the near future should it ever be possible, which thank God it is not, for a “Pax Germanica” and not a “Pax Anglica” peace to be declared.

In my travels through the United States, from North to South, from East to West, I have always been struck with the breadth of opinion prevailing there and the charity shown to individuals of all classes and nationalities. There is little of sectarianism in America, and religious differences hardly exist, thanks to the broad-mindedness shown by its citizens. Let us have a greater infusion of that spirit in our own Empire. It is almost impossible to conceive a difficulty there as we have now to face in Erin’s Isle. The great Federal principles adopted in America are of the utmost and most vital importance to the Anglo-Saxon race everywhere. Let us, who form such an important part of that race, not neglect but profit by the experience of our cousins across the seas. Each individual Anglo-Saxon, whether on this or that side of the Atlantic, should—and I am certain will—benefit by mutual experience.

Terrible as the war is, it is worth passing through its deep waters to weld together the two great English-speaking peoples in an indissoluble union which could have been brought about by no other means than the community of suffering and sacrifice the War involves. When America “came in,” as I always felt sure she would, the future of the world was rendered safe, not by her power and strength alone, but by her wise example in the system of democratic government she has established.

As an instance, I am at the present time trying to rouse interest here in the excellent system of patent laws which America has founded, stimulating and encouraging invention as those laws do. We cannot do better than follow her example.

In another respect, too, we should follow the wise coördination America has introduced with regard to her technical societies. In the great building in West 39th Street, New York, known as the Engineering Societies Building, some 300 ft. in height, are housed the five leading, and some two dozen smaller, technical societies representing a membership of no less than 58,254. There is one common meeting-place and one large library, containing 160,000 volumes of scientific and technical books. We are greatly in need of something of the same kind here, many of our technical societies having literally no home of their own.

Finally, I should like to take this opportunity of expressing my own indebtedness to the United States, from whom I have received so much hospitality, courtesy, and help in my way through life.

Hail, Columbia! May no limit be set to the greatness of her future. We know her citizens will ever support the cause of Justice and Freedom, not selfishly for their own benefit but for the benefit of the world at large. Within our Empire—the British Empire—there is and can be no jealousy of her success, and, if I may prophesy, I venture to say that future generations of the Great Republic and of the British Empire and the Dominions

will count it gain, notwithstanding the immense loss and sacrifice, that the Great War forged bonds of union between the two countries, ensuring for the inestimable advantage of the world at large, which can never be broken.

ENCOURAGEMENT OF SCIENCE IN GERMANY

By the courtesy of Sir Robert Hadfield, we have received the following communication relating to the development and encouragement of science and research in Germany at present. These statements have been translated by Sir Robert from various German sources, and are presented here as an indication of what Germany is doing not only to further her military power, but also to prepare for the period of trade rehabilitation to which she is looking forward after the close of the war.

KAISER WILHELM TRUST FOR PROMOTION OF WAR SCIENCE

The Kaiser has approved the foundation of a Trust with the name given above. The aim of the Trust is to further the development of scientific and technical aids to warfare, by uniting the scientific and the military forces of the country for work together. The scientific work is to be carried on by the following technical committees (or commissions):

- (1) Committee for the chemical raw materials, for the production of munitions-manufacturing materials.
- (2) Committee for chemical war materials (powder, explosives, gas, and the like).
- (3) Committee for physics, including ballistics, telephony, telegraphy, determination of targets and distances, measurements, and the like.
- (4) Committee for engineering and communication.
- (5) Committee for aeronautics.
- (6) Committee for obtaining and preparation of metals.

GERMAN UNION OF TECHNICAL AND SCIENTIFIC SOCIETIES

On March 4, 1917, at a meeting of the Verein Deutscher Eisenhüttenleute (German Iron and Steel Institute), held at Dusseldorf, Dr. Fr. Springorum said the war had intensified the need for closer co-operation of the German technical societies. Preliminary negotiations had therefore led to a combination of such societies, and the Verein Deutscher Eisenhüttenleute had gladly joined such Union and promised their support.

On April 19, in an article published in a German newspaper, it was stated that the managing committee of the Union had decided to create an intermediary agency between the technical world and scientific institutions for the carrying out of scientific and technical research work, so that industry not equipped for experimental work, specially smaller concerns, might be afforded an opportunity of having problems solved through the aid of the Union.

In November, the Union held its first general meeting at the premises of the Association of German Engineers in Sommerstrasse, under the Chairmanship of Privy Councillor Busley, at which the Imperial Government offices, Federal Council and legislative bodies were represented. The purposes and aims of the Union were explained. Herr Busley said their object was to establish a balance between science and practice, and that the technical world ought to be represented more than was hitherto the case in the legislative bodies.

Professor Dr. Wiedenfeld, of Halle, speaking on "Economics and Technics during and after the War" stated the blockade of the sea had necessitated the remodelling of the foundations of German economic life, the production from her own resources of raw materials and food, the utilisation of waste materials and the production of substitutes. Technical science could only meet these new requirements by disregarding the question of cost price and all considerations as to the possibilities of markets and the risks involved.

The above meetings and the objects of this important German Union of Technical and Scientific Societies are described more fully in the accompanying statements:

Objects of the German Union of Technical-scientific Societies

The managing committee of the German Union of Technical-scientific Associations has decided to create, at its offices, a department which is to act as an intermediary between the technical world and the scientific institutions of the Universities and the technical academies for the carrying out of scientific-technical research work.

Many problems, and likewise the special knowledge of the departments of work, are now-a-days so highly specialised that sometimes there are but few suitable operators available for dealing with a certain question in the scientific institutes. If now it were possible to direct all such problems to suitable operators in each instance, a very material advantage might be gained with a minimum expenditure of labor.

On the one hand the great intellectual and material resources which are extant in the equipment of the scientific institutions of universities and technical academies and in the knowledge and experience of their heads, might be rendered serviceable to German industry to a greater extent than hitherto. On the other hand, industry—as far as it is not itself equipped for carrying out the task by means of its own arrangements and staff or other connections, hence in particular medium-sized and small concerns are less amply equipped with experimental research arrangements—will be afforded the possibility of having questions which would otherwise have to be left unsolved, conducted into proper channels for effecting their solution, through the aid of the Union. Even to large industrial establishments it might sometimes be not undesirable to come in this way into touch with academicians who are willing to judge as to complicated questions from the scientific standpoint, yet in cohesion with technics.

A large number of heads of institutions in the departments of applied and physical chemistry, physics, electro-technics and engineering science have declared themselves willing to undertake such work introduced to them through the intermediary agency. Further, those of special experience in each of the departments named have placed themselves at the disposal of this agency with a view to assisting it in the selection of suitable operators for the purpose in question.

The German Union and the heads of the scientific institutions hope that this agency will be of value and prove very useful not only for the duration of the war but also in the subsequent economic life of peace-time.

The Union therefore requests industrial works engaged in the departments of (a) chemistry; (b) applied physics; (c) electro-technics; (d) machinery construction; (e) engineering science in general, to address enquiries to *Vermittlungsstelle des Deutschen Verbandes*, 4A Sommerstr., Berlin, N. W.

Technics During and After the War

The German Union of Technical-scientific Societies, which has recently been formed by the combining of thirteen associations and unions, held its first general meeting on the premises of the Association of German Engineers in Sommerstrasse, where the Chairman, Privy Councillor Busley, after welcoming those present—among whom the Imperial Government offices, the Federal Council and legislative bodies were represented by members—explained the purposes and aims of the Union.

Herr Busley said that their object was to establish a balance between science and practice. Many a technical task could not be carried through without participation and collaboration of several branches of science; the metallurgist required the co-operation of the technician, the architect that of the engineer, etc. An influence was also to be exerted on technical instruction and education, and towards ensuring that the academically trained technician should be admitted to all administrative departments of the Federal States. The technical world ought to be represented, more than was hitherto the case, in the legislative bodies. The Union had also applied to the authorities with a view to being consulted in the preparatory work of drafting regulations or enactments. Unfortunately, hitherto, the Imperial Treasury alone had availed itself of their advice, in the preparatory work for the taxation of coal and sources of energy. Finally, the speaker stated that a desire had been expressed that an Austrian and Hungarian Section should be attached to the Union, as to which resolutions were still to be passed.

Professor Dr. Wiedenfeld (Halle) then spoke on "Economics and Technics during and after the War." The speaker showed, in a very exhaustive manner, how, in former days, Germany could manage well with her own production, how subsequently she became more and more dependent on foreign countries owing to the increase of her population, and was then subjected, by the blockade of the sea, to the necessity of remodelling all the foundations of her economic life, of producing from her own resources, raw materials and food. Technical science could only meet these new

requirements by fundamentally disregarding the question of cost price, which formerly, in competing with other countries, was necessarily one of the foremost considerations. Disregarding all considerations as to the possibilities of the market and the risk involved, substitutes were produced by calling in the aid of new modes of production and devoting thereto all human powers. Although not all of these new conditions and products can be carried over into times of peace, nevertheless the old economic conditions cannot be reverted to. "What has been will never return," nor would this be even desirable. He said that technical science had been endeavouring to come to the aid of economic life in a threefold manner.

1. By procuring the raw materials formerly obtained from abroad, partly by the re-establishment of industries which had become unremunerative (production of manganese, increase of the production of iron, production of sulphur, intensification of agriculture).

2. By promoting the technical tendency, already existing in pre-war times, towards increased utilisation of waste products. The term "non-utilisable substance" has been eliminated by the war. The speaker emphasised in this respect obtaining lubricants from coal tar, and supplying clothing requirements by utilisation of waste material.

3. By producing substitutes, such as nitrogen from the air, and the production of substances by synthetic processes, where the natural way is no longer available, as for instance the cattle food produced from straw.

The speaker recalled a dictum of His Excellency Professor Fischer: "I cannot imagine any substance for which a substitute could not somehow be found." In the speaker's opinion too much regard had been paid, during the early part of the war, to the quality of the production, which however became impossible with the continued duration of the war. The speaker also found fault with the multiplicity of Government authorities controlling construction, which had already manifested itself in peace times to the prejudice of German production. With a view to the projects, the speaker demanded that even after the war we ought to aim at a reduced utilisation of certain raw materials. Production would assume an unfavourable aspect in certain departments owing to the high expense for industrial war installations. In this respect amortisation during the war of these expenses for war installations would be necessary. Further, wherever materials produced wholesale are in question, the speaker would be in favor of monopolies, though not necessarily state monopolies. He held that it would only be by strictly regulated syndicates that steadiness in the movement of prices could be established, and an assurance of remunerativeness, favourable to the display of technical science, and consequent brisk investment of capital, obtained. The speaker concluded by attempting to lay down guiding principles for the collaboration of technical science and enterprise, which cannot do without each other.

RESEARCH ON IRON AND STEEL

The German proposition is to found and establish a special institution and research laboratory to be entirely devoted to researches on iron and steel. Surely we in this country will not allow this action of the enemy to go unchallenged. Whilst Great Britain has several important laboratories devoted to research on iron and steel, there is certainly required a general building, and common meeting place for the following important institutions.

- (a) Iron and Steel Institute.
- (b) Institute of Metals.
- (c) Institution of Mining and Metallurgy.
- (d) Institution of Mining Engineers.
- (e) Faraday Society.
- (f) Society of Chemical Industry.
- (g) And others.

On March 4, 1917, at a general meeting of the Verein Deutscher Eisenhüttenleute (German Iron and Steel Institute) held at Dusseldorf, Dr. Fr. Springorum, during the course of his address, said the committee appointed by the Board of that Institute had recently discussed the subject and recognised the necessity of promoting progress in metallurgy by the establishment of a special research institute probably to be attached to the Kaiser Wilhelm Society.

This was followed on June 19, 1917, by a further meeting of the same Institution at which a resolution was unanimously passed with regard to the establishment of such an institution and research laboratory to be devoted to research on iron and to be attached or affiliated to the Kaiser Wilhelm Society, an important new German association.

On July 6, 1917, at a meeting of the Senate of the Kaiser Wilhelm Society, held under the Presidency of Professor Von Harnack, the Senate declared itself in agree-

ment with the proposal of the Verein Deutscher Eisenhüttenleute to establish this institute and laboratory for research on iron and steel.

On July 28, 1917, reference was made to the meeting of the Verein Deutscher Eisenhüttenleute held on June 19, and after discussing the foundation and site of the building the writer stated that, "the means for building and maintaining the Institute, except a small contribution from the Kaiser Wilhelm Society, will be raised by the iron and steel industry of Germany."

Finally, from the latest information in the possession of the compiler of this present statement, there was held on Nov. 13, 1917, the first meeting of the "Curatorium" (Trustee Committee) of the Kaiser Wilhelm Institute with regard to the establishment of the research institute and laboratory for research on iron and steel in the Stahl und Eisen Building in Dusseldorf, when Dr. Springorum was elected Chairman.

It may be added that the Kaiser Wilhelm Society was founded by the initiative of Emperor William II in January, 1911, for establishing and maintaining in a scientific manner independent institutes for research in the sphere of physical science. It has assisted in the foundation of the Institute for Chemistry; Institute for Experimental Therapy; Institute for Coal Research; Institute for Labour Physiology; and now the Institute for Research on Iron and Steel; also (1914) projected the Biological Institute and the Institute for Aerodynamics and Hydrodynamics.

The President is Dr. Harnack and the first Vice-president is Dr. Krupp von Bohlen and Halbach. Half the members are elected, the other half nominated by the Emperor and the Committee of Management. The election by the Senate and confirmation by the Emperor carries with it the obligation of a contribution of £1000 with an annual contribution of £50.

PRESENT CONDITION OF THE MINING AND METALLURGICAL INDUSTRIES IN GERMANY

The following paragraphs have been extracted from a recent publication of the U. S. Department of Commerce, *Miscellaneous Series*, No. 65, "German Trade and the War," which portrays the industrial, commercial and economic conditions of Germany, at the present time, and has been compiled largely from sources published in Germany.

Iron and Steel

The Krupp company, the greatest of the German munition works, was faced at the outbreak of the war with the disappearance of its great international business, but this was amply compensated by orders from Germany and her allies, and the activity of the company has been greatly extended. The general meeting of December, 1914, voted an increase in the capital to 250,000,000 marks. The gross profits of the company, amounting to 61,900,000 marks in 1912-13, have been more than doubled during the war. The gross profits were 128,260,000 marks in 1914-15 and 143,360,000 in 1915-16. Large sums have been written off; 10,000,000 marks have been placed in the pension fund during the war, and 5,000,000 were appropriated for workmen's dwellings in 1915. Thirteen million marks have been devoted to war assistance in the last three years. The assets of the company were valued at 967,000,000 marks at the end of 1916. For the year 1916-17, the company paid a dividend of only 10 per cent., but set aside 88,425,000 marks for depreciation.

The Bismarckhütte in Upper Silesia, capitalized at 16,000,000 marks, with a bonded indebtedness of 7,907,500 marks in 1913-14, reported 3,912,000 marks of net revenue from operation for that year. During the three years of war the revenue increased successively to 8,077,000, 11,805,000, and 16,994,000 marks. While the capital remained unchanged, and the bonded indebtedness was but slightly reduced, the dividends paid during the last four years were increased from 9 per cent. in 1913-14 to 15, 25, and 30 per cent. during the war. During the year 1916-17 the amount written off, chiefly on the works and plant account, was 10,553,000 marks, or nearly as much as the total set aside during the three preceding years. The turnover for that year reached a sum many times the amount of the capital. At the end of 1916 the company's shares were quoted at 275, as against 144 at the end of 1913.

During the year 1916-17 the Mannesmann Tube Works, of Dusseldorf, earned a gross profit of 52,265,000 marks, or three times the average profit of the last years of

peace. The company is capitalized at 72,000,000 marks. During the last four years the dividend rates have been 7½, 10, 15, and 18 per cent.

The "Phoenix," a great mining and iron-works company of Westphalia, capitalized at 108 million marks, has increased its earnings with each successive year of the war. In 1914-15 the gross profits from operation were 28,086,000 marks, 8 million less than in the last year of peace, but in 1915-16 the earnings rose to 46,790,000, and in 1916-17 to 59,952,000 marks. The company's report points out, however, that the profits have been made largely at the cost of a reduction of stocks and depreciation of the plant, which has been exposed to unusual wear and tear, while due care could not be paid to maintenance and renovation, so that a large outlay may be necessary when peace comes. A dividend of 20 per cent. was distributed in 1916-17, and in 1915-16, as against 12 per cent. in 1914-15, and 10 in 1913-14. The market price of the company's shares rose from 232 at the end of 1913 to 245 at the end of 1916 and 266.25 at the end of 1917.

Potash

The potash interests have overlooked no opportunities for profit during the war, High prices for the securities of the potash companies have prevailed. In February 1918, it was reported that the Deutsche Kaliwerke had taken over the companies owning the Bernburger works, the Groena works, and the Erbprinz works and was negotiating for the control and absorption of other companies. The consolidations were undertaken in part to effect merchandising savings and in part to forestall suggested schemes of Government monopoly.

Coal Mining

Immediately after the outbreak of the war the mining of coal stopped almost completely for a time. When production was resumed, the output was considerably smaller than in normal times, as thousands of miners had been called to the colors. Imported workers, women, prisoners of war, and furloughed soldiers were sent to the mines, and the output increased gradually until it reached nearly 75 per cent. of the normal in July, 1915. The production of brown coal was about 90 per cent. of the normal at the end of the first year of war, normal in the second year, and was later increased still further. The production in the first year of the war was hardly sufficient for the domestic needs, but Germany had to export coal to the neutral countries in payment for imports. Two central bureaus, one in the east and another in the west, were established to regulate the exports to neutral countries, which had been reduced 50 per cent.

The number of mine workers was increased in the summer of 1917 by the furloughing of 19,000 soldiers who are miners or mine managers by trade or profession. This resulted in increased production, but the output was still insufficient. In July, 1916, the average output per man per shift was 1.01 metric tons; in April, 1917, the Langenbrahm mine, working under favorable conditions, showed an average of only 0.9 ton, and its total daily production had declined in the meantime from 1260 to 784 tons.

The manufacture of coke is of particular importance in connection with the valuable by-products. The industries are extending their use of coke wherever it is possible, and the demand for this fuel has increased considerably. Both the mines and the coke ovens are suffering from a lack of proper equipment, resulting frequently in a temporary stoppage of work. It is difficult and at times even impossible to replace worn-out parts with new ones, and repairs take too much time. Owing to the high prices of plant equipment and the high wages, which continue to register a steady increase, the cost of production has risen very considerably. For the Langenbrahm mine the cost of production per metric ton of coal was 8.69 marks (\$2.07 at normal exchange) in July, 1916, and 16.16 marks (\$3.85) in April, 1917.

Metal Mining

Owing to war conditions, wasteful methods were resorted to in the mining of minettes, certain other iron ores, and the zinc ores of Upper Silesia, the size of the output being of primary consideration. In some iron mines and in one pyrites field the average yield was increased, but the total production was supplemented by imports from Sweden. The ores of the rarer metals were exploited with greater intensity

high prices and technical improvements making possible the utilization of many low-grade ores. In many cases the limit of profitable exploitation was lowered considerably. The smelters of ferrochrome now work up ores containing as little as 24 per cent. of Cr_2O_3 , whereas in former times only ores with 48 or 50 per cent. could be worked profitably. In the working of pimelite, a nickel ore, the limit of profitable exploitation was reduced from 2.5 to 1.5 per cent. The Geological Institute is reported to have succeeded in extracting nickel and cobalt from mine springs containing these metals. Bauxite containing but 40 per cent. of Al_2O_3 is now utilized for the extraction of aluminum. Experiments have been made with the extraction of aluminum from clay. In the exploitations of wolframite the limit has been reduced from 1 to 0.06 per cent., chiefly, however, under the stimulus of high prices. For copper schist the limit has been lowered from 2.5 to 1 or even 0.7 per cent. The high prices of silver have made possible the exploitation of certain abandoned silver mines.

Substitute Materials

Iron and zinc have largely replaced the other metals. By extensive experiments the Germans are said to have succeeded in refining zinc so that it can be used as a substitute for brass for certain purposes, such as shell fuses. It has been employed in the manufacture of electric cables. Various zinc and lead alloys have also been utilized. One of the Breslau tin-foil factories is reported to have succeeded in producing zinc foil. Cardboard boxes have largely replaced tin cans.

Germany produces only a little over one-sixth of the copper needed by its industries. When importation was stopped by the war it became necessary to construct electric conductors of other materials. Iron and zinc are employed for that purpose with success, according to a report presented to the Society of German Machinery Engineers at Berlin.

Zinc has to be refined by a special spraying process, giving it the proper flexibility before it can be used for the manufacture of wire. The zinc wire must be protected against heat exceeding 130°C ., and against air currents; hence it cannot be used as a free conductor. In other respects the behavior of fixed zinc wires and zinc cables is said to be satisfactory. Zinc conductors also can be safely wound on dynamos or transformers. On a suburban line of the Berlin electric railway, zinc has been used to effect rail bond connections. Instead of employing special copper bonds, the surfaces of contact between the fishplates and the rails are sprinkled with liquid zinc, which is said to give a better electric connection than has been obtained by the old method.

According to the *Neue Zürcher Zeitung*, systematic investigations into the properties of coal have been carried on by the Kaiser Wilhelm Institut für Kohlenforschung and have yielded important industrial results. The treatment of coal with liquid sulphurous acid at ordinary temperatures has produced $\frac{1}{2}$ per cent., by weight, of viscous, golden-yellow mineral oils. A process has also been elaborated by which through heating naphthalene under pressure, in the presence of aluminum chloride, an oil is produced that can be used for illuminating purposes in the same manner as petroleum. Benzol and mixtures of benzol with alcohol are employed as substitutes for gasoline as automobile fuel.

FOURTH NATIONAL EXPOSITION OF CHEMICAL INDUSTRIES

The fourth National Exposition of Chemical Industries will be held in the Grand Central Palace, New York, during the week of Sept. 23, 1918. Dr. Bacon, of the advisory committee, is now head of the Chemical Warfare Section of the National Army, and a member of General Pershing's staff. The coming Exposition will be the largest ever held, and it will be necessary to use four floors of the Grand Central Palace. The exposition is a war-time necessity, and regarding it as such, each exhibitor is planning his exhibit so that it will be of the greatest benefit to the country.

The South is again sending exhibits from some sections, and Canada is taking the opportunity of presenting the materials it has available for development by the chemist and financier. A section for the glass and ceramic industry has been added, with which the American Ceramic Society is coöperating.

The program for the exposition is in active preparation and will be a series of symposiums on the "Development of Chemical Industries in the United States, notably since July, 1914."

STANDARDIZATION OF COMPRESSED-AIR TERMS

Upon the recommendation of its Technical Committee, The Compressed Air Society has adopted the following definitions of certain terms.

Displacement.—The displacement of an air compressor is the volume displaced by the net area of the compressor piston.

Capacity.—The capacity should be expressed in cubic feet per minute, and is the actual amount of air compressed and delivered, expressed in terms of free air at intake temperature and at the pressure of dry air at the suction.

Volumetric Efficiency.—Volumetric efficiency is the ratio of the capacity to the displacement of the compressor, all as defined above.

Compression Efficiency.—Compression efficiency is the ratio of the work required to compress isothermally all the air delivered by an air compressor to the work actually done within the compressor cylinder, as shown by indicator cards, and may be expressed as the product of the volumetric efficiency (the intake pressure and the hyperbolic logarithm of the ratio of compression), all divided by the indicated mean effective pressure within the air cylinder or cylinders.

Mechanical Efficiency.—Mechanical efficiency is the ratio of the air indicated horse-power to the steam indicated horse-power in the case of a steam-driven, and to the brake horse-power in the case of a power-driven machine.

Overall Efficiency.—Overall efficiency is the product of the compression efficiency and the mechanical efficiency.

The Society further recommends that the use of other expressions of efficiency be discontinued.

NERVE SPECIALISTS IN THE INSTITUTE

As a means of lending weight to the activities of its Committee on Industrial Organization, with particular reference to the work on mental hygiene and the prevention of illness, the Institute has recently invited a number of members of the medical profession to become Associates of the Institute. We are glad to observe that the wisdom and utility of this departure have been appreciated by the gold mining industry, in testimony whereof we are pleased to publish the accompanying sketch from the pen of Mr. P. A. Robins, Managing Director of the Hollinger

mine, Timmins, Ontario, which we have received through the courtesy of Mr. C. H. Poirier.



Extract from *Porcupine Advance*.—The American Institute of Mining Engineers is handling war conditions with great foresight. At a recent meeting they elected to membership _____, nervous disease specialist and consulting physician to the City Sanatorium of _____. It is understood that a move is on foot to make all nerve specialists honorary members of the Institute, as it is believed this will greatly benefit those members who are engaged in gold mining.

MANGANESE ORE IN OREGON

Henry M. Parks, director of the Oregon Bureau of Mines and Geology, has supplied the following information regarding a recent discovery of manganese ore in Jefferson County, Oregon, about seventeen miles southeast of the railroad at Eagle Point, a station on the P. & E. Railway. The occurrence is about five miles southeast of Lake Creek Post Office and near the confluence of Lost Creek with the south fork of Little Butte Creek.

The manganese ore occurs as psilomelane and pyrolusite, disseminated through a flat bed of volcanic tuff breccia; at a point where the bed was penetrated by a churn drill hole, the thickness of the ore-bearing stratum was 30 ft. Development thus far has consisted of open-cuts, one of which exposes a face about 40 ft. high and 75 ft. broad. Other smaller open-cuts have followed the bed for a distance of 400 yards.

The nodules of manganese mineral vary from a maximum of 25 to 50 lb. down to the size of beans and others as small as mustard seed. These grains, when clean, average from 55 to 58 per cent. manganese. A 12-ft. groove sample in the face of the main open-cut yielded 14.86 per cent. manganese.

The peculiar occurrence of the manganese nodules should present but slight difficulty in concentration. A small experimental mill was built last winter, comprising gyratory crusher, rolls, and jigs, which,

in spite of the usual operating difficulties at a new mill, has produced about 200 tons of concentrate averaging 50 per cent. manganese, and 10 to 14 per cent. silica.

THE PERSONAL DUTY OF INTELLIGENT MEN AT THE POLLS

The Editor, with the full realization of his own forgetfulness of political duties until it is brought to his attention perhaps by some unfavorable election already consummated, wishes to remind the thinking men who compose the body of the membership of this Institute that never before in the history of the country has it been so important that we should be represented at Washington, and in our State Legislatures, by men of vision, high character, courage, broad experience in the more important affairs of life, and undoubted loyalty. Let us all endeavor to secure the nomination and election of this type of man, and let us, each in his own district (which collectively will represent practically every important locality in the Union) carefully scrutinize all candidates for election and work for the best one who seems to have any chance of being successful. Let us place ourselves in communication with political leaders, newspaper men of prominence, and public men generally, strengthening our own appreciation of the importance of the election at this time and coöperating for the purpose of obtaining candidates of the highest character. Upon the men of intellect depends chiefly the burden of wise selections at this time. Congressional elections will occur this Fall in the following states:

Maine
New Hampshire
Massachusetts
Rhode Island
New Jersey
Delaware
Maryland
Virginia
West Virginia
Kentucky
Michigan
Illinois
Minnesota
Iowa
Kansas
Oklahoma

Nebraska
South Dakota
Montana
Wyoming
Colorado
New Mexico
Idaho
Oregon
North Carolina
South Carolina
Georgia
Alabama
Louisiana
Arkansas
Tennessee
Texas

The Editor offers these suggestions in an absolutely non-partisan spirit, but takes the liberty of urging that in newspaper editorials, political speeches, private debates, and in all conversation, whether it is liable to be over-heard or not, no words shall be said which will give comfort to the enemy or weaken or handicap the present authorities in the performance of their duties.

PERSONAL

The following is an incomplete list of members and guests who called at Institute headquarters during the period June 10, 1918 to July 10, 1918.

F. C. Alsdorf, Tucson, Ariz.	Emory M. Marshall, Camp Raritan, N. J.
Juan F. Brandes, Santa Barbara, Cal.	Jacques S. Negru, Camp Niagara, Ont.
H. Smith Clark, Kansas City, Mo.	Arvid E. Nissen, High Bridge, N. J.
J. S. Cunningham, Charleston, W. Va.	Richard G. Place, So. Strafford, Vt.
W. G. Eberhardt, Tucson, Ariz.	Frank H. Probert, Berkeley, Cal.
M. Eldredge, Bombay, India.	Martin A. Roudabush, Osterburg, Pa.
A. D. R. Galloway, Accra, W. Africa.	P. H. Royster, Minneapolis, Minn.
J. F. Hanst, Harrisburg, Pa.	J. L. Schueler, Peoria, Ill.
B. B. Hood, Chrome, N. J.	Henry B. Smith, New Britain, Conn.
Paul S. King, Wilmington, Del.	W. G. Sommer, Peoria, Ill.
E. D. Kinney, Anaconda, Mont.	A. L. Toenges, Roanoke, Va.
E. W. Kohl, Jr., Philadelphia, Pa.	G. D. B. Turner, Butte, Mont.
James W. Love, Knoxville, Tenn.	A. T. Ward, Bellefonte, Pa.

Edwin A. Austin, formerly with the Yukon Gold Co., is superintendent of the Elkoro mine at Jarbidge, Nev.

John W. Beard is now with the Cia Minera de Penoles, Ojuela, Dgo., Mexico, via Mapimi.

R. S. Bonsib has accepted a position with the United States Emergency Fleet Corporation as District Safety Engineer, San Francisco, Cal.

Albert Burch has been appointed by the Bureau of Mines to encourage the mining of chrome.

F. B. Caldwell is working for the U. S. Bureau of Mines, under Albert Burch, in the investigation of chromite deposits.

W. A. Carlyle has taken over the duties (in addition to his own) formerly assigned to E. P. Mathewson with the British America Nickel Corporation, at Sudbury, Canada.

R. M. Catlin received the honorary degree of Doctor of Science at the recent commencement of Rutgers College, New Brunswick, N. J.

S. K. Dahl is giving up his position as mill superintendent with the Messina Mines, which have been suspended, and is returning to this country.

Algernon Del Mar has become manager of the Techatticup mines, El Dorado Canyon, Nev.

Robert Dye has succeeded D. L. Forbes as manager of the Teck-Hughes at Kirkland Lake, Ont., Canada.

J. O. Elton, superintendent of the Anaconda company's electrolytic zinc plant at Great Falls, Mont., is doing special work with the U. S. Bureau of Mines. **R. B. Caples** takes charge of the plant in his absence.

George H. Gibbs has resigned his position as engineer at Messrs. T. & I. Bradley & Sons, Ltd., Darlaston blast furnaces, Darlaston, and is now located at "Belmont," Litchfield Road, Rushall, Walsall, England.

William D. Gordon, for the past 7 years manager of The Mine & Smelter Supply Co. at El Paso, has been elected president of Camphuis, Rives & Gordon, Inc., and has opened American headquarters for the company at 81 New Street, New York, N. Y.

E. Harms, for the past 16 years in charge of metallurgical operations of the Torreón, Mexico, lead and copper smelter, has resigned and is now located at El Paso, Tex.

M. R. Hull is now with the Nevada Cons. Copper Co., McGill, Nev.

Joseph Inch has resigned his position as chief engineer to the Compania de Minas de Cobre de Gatico and accepted a position as manager of the Sociedad de las Minas de Cobre de San Bartolo, San Pedro de Atacama, Antofagasta, Chile, S. A.

Jerome B. Landfield, formerly employed by the Russian Government in the capacity of mining engineer, has gone to Washington to advise on Russian affairs.

J. A. Mahoney has severed relations with the Westinghouse Electric & Manufacturing Co. of East Pittsburgh, Pa., and has begun practice as a consulting mechanical and electrical engineer in New York.

H. P. Nagel, Jr., has been appointed mine superintendent, Sunnyside Mining & Milling Co., Eureka, Colo.

George W. Paymal has accepted a position as superintendent of the Yellow Aster Mining & Milling Co., Randsburg, Cal.

Richard G. Place has accepted a position as chief chemist, Vermont Copper Co., South Strafford, Vt.

Charles A. Randall has been made assistant to Douglas A. Mutch, general manager for the Dome Lake Mining & Milling Co.

H. R. Robbins has severed his connection with the Granby Cons. Mining, Smelting & Power Co., Ltd., for the duration of the war, and has been commissioned Captain, National Army, assigned to special duty with the General Staff in Washington.

Selden S. Rodgers is now superintendent of crushing and flotation, Anaconda Copper Mining Co., Anaconda, Mont.

Samuel W. Traylor has been appointed Chairman of the Board of the Traylor Engineering & Manufacturing Co.

POSITIONS VACANT

Draftsman and transitman for coal mine work in Middle West. Salary \$125 per month. No. 277.

Men capable of taking charge and superintending the construction of plants. No. 331.

Position for mining engineer in district with two large operating mines, four mines under development, and two mines temporarily closed, because of water conditions. Another assistant is desired. Excellent school facilities in model town; house available for engineer. Would consider recent graduates. No. 332.

Engineer or firm of engineers competent to survey and estimate the extent and the contents of a deposit of clay in the southern mountains of Pennsylvania, and to figure on the cost of getting the material, presumably through a tunnel running into the side of the hill on which the property is located, as this is the method by which similar properties in the vicinity are being worked. Prefer to have some one who would bid on the actual work of opening up the deposit. No. 333.

Four assistant division foremen. These men must be Americans who can talk Spanish, and must be good miners and familiar with handling large stopes by the cut-and-fill, square-set and top-slice methods. Salary \$200 gold per month. No. 334.

Large progressive foundry company wants services of man with exceptional ability to analyze cause and suggest cure for defective losses

in highly specialized foundry. Salary limited only by the qualifications of the applicant. State experience and achievements, also salary expected. Foundry located in large city on Great Lakes. No. 335.

A large distributing house desires a metallurgical chemist, around 30 years of age, who would find special interest in the constructive criticism of hardware and metal products generally, from the standpoint of identity and quality of materials, and accuracy of description. For the man of just the right ability, personality, training, and experience, that is, for the man capable of making his own job, the opportunity is one of much promise. No. 336.

ENGINEERS AVAILABLE

(Under this heading will be published notes sent to the Secretary of the Institute by members or other persons introduced by members.)

Experienced mining engineer, Columbia School of Mines graduate, practical experience in drifting, shaft sinking and development work, also in mining, operating and equipping iron, copper, and zinc properties. Married, age 32, available at once. Open for position as superintendent or assistant. No. 462.

Member, age 33, married, desires position as mining engineer or engineering executive. Twelve years experience as mining engineer, geologist, and chief engineer of iron and copper properties. Experience in United States, Mexico and South America. Fluent Spanish. Technical graduate. Minimum salary \$3000. No. 466.

Member, technical, general superintendent and mill superintendent. Well experienced in latest methods of ore reduction, especially on copper and complex ores. Draft exempt. Not less than \$250 per month considered. No. 469.

Consulting mining geologist, member of Geological Society of America and A. I. M. E., Professor of Geology and Mineralogy, Lawrence College, desires temporary position during summer in mine surveying, mining methods, expert mine valuation or any exploration work or mine development. Applicant has had nearly three years' experience in gold mining in Mexico and many years professional mine examination work in all regions of Western U. S. Terms reasonable. No. 470.

Member, mining engineer, age 46, desires engagement as manager of mining properties, coal or metal mines. Education and 25 years experience in all branches of mining. Have been successful with labor in the management of large properties. No. 471.

Member, age 37, American lawyer, responsible, tactful, excellent knowledge of Spanish and Latin-American customs. Ten years' successful experience directing litigation, securing mining and water-power concessions, managing mining company, transportation and general business in South America. Best reference. At present employed. Would consider employment with responsible concern in Western States or South America. No. 472.

Member, technical graduate, age 34, married, dependable, desires position as manager or superintendent of responsible concern. Experience covers management of mines and of mills treating gold, silver, copper, lead, and zinc ores. Thorough knowledge of flotation. At present employed. Available on one month's notice. No. 473.

Mining Engineer, 56, is desirous of becoming associated with first-class (not necessarily large) mining enterprise, preferably in Northwest. Has had broad experience in deep mining; ore selling, and some metallurgical experience. Has carried on successful mining operations for years. Now Cons. Engineer in Southwest. No. 474.

Mining engineer and geologist, member, 37, married, desires position in progressive concern. Technical knowledge and 10 years' practical experience in mine operations, exploration, examination, etc. Last 4 years engaged chiefly on war minerals. Used to any climate. Energetic, and good organizer. Excellent health. Available from July. Highest credentials. No. 475.

Member, graduate mining engineer with 10 years' practical experience. Now superintendent of a mining company in Utah, desires similar position elsewhere. No. 476.

Member, mining engineer, age 33, single, technical graduate, over 8 years' experience, desires a position with a coal company, preferably in the West. No. 477.

Member, mining engineer, technical graduate, age 31, married, 9 years' experience in West and British Columbia as engineer and superintendent. Will go anywhere within United States, but will not consider temporary positions. Available two weeks' notice. References. No. 478.

Member, age 32, married, university graduate, Ph. D., petroleum geologist and chemist with 5 years' experience in the Mid-continent oil fields, speaks French, German and English, desires position with responsible concern. South America or West Indies preferred. A-1 references. No. 479.

Member, age 31, technical graduate, 8 years' experience in copper and nickel mining, desires to make a change. No. 480.

FORTHCOMING MEETINGS OF SOCIETIES

Organization	Place	Date 1918
American Chemical Society.....	Cleveland, O.	Sept.
American Society of Sanitary Engineers.....	Chicago, Ill.	Sept.
National Petroleum Association.....	Atlantic City, N. J.	Sept.
American Institute of Mining Engineers.....	Colorado	Sept. 2-7
National Association of Stationary Engineers....	Cincinnati, O.	Sept. 9-13
Association Iron, Steel, Electrical, Engineers....	Baltimore, Md.	Sept. 9-14
British Iron and Steel Institute, Autumn Meeting	London, Eng.	Sept. 12-13
National Exposition of Chemical Industries.....	New York, N. Y.	Sept. 23-28
American Electrochemical Society.....	Princeton, N. J.	Sept. 30- Oct. 2
Institute of Metals Division, A. I. M. E.	Milwaukee, Wis.	Oct. 8-11
Iron and Steel Members, A. I. M. E.	Milwaukee, Wis.	Oct. 8-10
American Foundrymen's Association.....	Milwaukee, Wis.	Oct. 7-12
American Museum of Safety and Sanitation, Exposition.....	St. Louis, Mo.	Oct. 7-12
National Safety Council.....	St. Louis, Mo.	Oct. 14-17
Business Show.....	New York, N. Y.	Oct. 21-26

LIBRARY

AMERICAN SOCIETY OF CIVIL ENGINEERS
 AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS
 AMERICAN SOCIETY OF MECHANICAL ENGINEERS
 AMERICAN INSTITUTE OF MINING ENGINEERS
 UNITED ENGINEERING SOCIETY

HARRISON W. CRAVER, DIRECTOR

The library of the above-named Societies is open from 9 A.M. to 10 P. M. except on holidays. It contains about 70,000 volumes and 90,000 pamphlets, including sets of technical periodicals and publications of scientific and technical societies.

Members of the Institute, with few exceptions, are forced to spend a portion of their time in localities isolated from sources of information. To these the Library, through its Library Service Bureau, can render valuable service through correspondence; letters requesting information will receive especial attention. The Library is prepared to furnish references and photographic copies of articles on mining and metallurgical subjects; to determine the existence of mining maps, and to furnish general information on the geology and mineral resources of all countries.

All communications should be made as definite as possible so that the information received may be what is desired and not include collateral matter which may not be of interest. The time spent in searching for such collateral matter will be saved, and the information will be sent more promptly and in more usable shape.

Library Accessions

INCOMPLETE LIST CLASSIFIED BY SUBJECTS

Mineral Resources

- ALASKA, THE LAKE CLARK-CENTRAL KUSKOKWIM REGION. (U. S. Geological Survey. Bulletin 655.) Washington, 1917.
- , COSNA-NOWITNA REGION. (U. S. Geological Survey. Bulletin 667.) Washington, 1918.
- CANADA, IRON ORE OCCURRENCES IN, VOL. II, WITH MAPS. Ottawa, 1917.
- VALUE OF PEAT FUEL FOR THE GENERATION OF STEAM. (Canada. Dept. of Mines. Bulletin No. 17.) Ottawa, 1917.
- TEST OF SOME CANADIAN SANDSTONES TO DETERMINE THEIR SUITABILITY AS PULP-STONES. (Canada. Dept. of Mines. Bulletin No. 19) Ottawa, 1917.
- MINERAL PRODUCTION OF CANADA, PRELIMINARY REPORT, 1917. Ottawa, 1918.
- PRODUCTION OF CEMENT, LIME, CLAY PRODUCTS, STONE, AND OTHER STRUCTURAL MATERIALS IN CANADA, 1916. (Mines Branch, No. 470.) Ottawa, 1917.
- MINNESOTA, STRUCTURAL AND ORNAMENTAL STONES OF. (U. S. Geological Survey. Bulletin 663.) Washington, 1918.
- NOVA SCOTIA, DEPARTMENT OF PUBLIC WORKS AND MINES. Annual Report of the Mines, 1917. Halifax, 1918.
- OIL AND GAS FIELDS OF THE UNITED STATES (2-sheet wall map of U. S. corrected to March, 1917).
- OIL AND GAS POSSIBILITIES IN THE BELTON AREA. (Missouri Bureau of Geology and Mines.) Rolla, 1918.
- PHILIPPINE ISLANDS, MINERAL RESOURCES, 1916. Manila, 1917.

GOLD DEPOSITS OF THE RAND. By C. B. Horwood. London, 1917.

WYOMING GEOLOGY, BIBLIOGRAPHY AND INDEX, 1823-1916. (Wyoming, Geologist's Office. Bulletin No. 17.) Cheyenne, 1918.

Metallurgy and Mining

ALUMINUM: ITS HISTORY, OCCURRENCE, PROPERTIES, METALLURGY AND APPLICATIONS, INCLUDING ITS ALLOYS. Ed. 2. By Joseph W. Richards. Philadelphia, 1890.

ALUMINUM AND ITS CONGENERS, INCLUDING THE RARE EARTH METALS. By H. F. V. Little. (Volume IV of "Text-book of Inorganic Chemistry). London, 1917.

MODERN COKING PRACTICE. Vols. 1-2. Ed. 2. By J. E. Christopher. London, 1917.

CONCRETE FOR INDUSTRIAL HOUSING. Chicago, 1918. (Gift of Portland Cement Association.)

METAL MARKET YEAR-BOOK, "THE IRONMONGER," 1918. London, 1918.

RELATIVE RESISTANCE OF VARIOUS HARDWOODS TO INJECTION WITH CREOSOTE. (U. S. Dept. of Agriculture. Bulletin No. 606.) Washington, 1918.

Disabled Soldiers

(Gift of Red Cross Institute for Crippled and Disabled Men)

DEVELOPMENT IN ENGLAND OF A STATE SYSTEM FOR THE CARE OF THE DISABLED SOLDIER. By John C. Faries.

ORGANIZATION, WORK AND METHOD OF THE RED CROSS INSTITUTE FOR CRIPPLED AND DISABLED MEN. By Douglas C. McMurtrie.

RECONSTRUCTING THE CRIPPLED SOLDIER. By Douglas C. McMurtrie.

REHABILITATION OF THE WAR CRIPPLE. By Douglas C. McMurtrie.

VOCATIONAL RE-EDUCATION FOR WAR CRIPPLES IN FRANCE. By Grace S. Harper.

TOURVIELLE: A TRADE SCHOOL FOR WAR CRIPPLES. By Gustave Hirschfeld.

General

AMERICAN INSTITUTE OF MINING ENGINEERS. General Alphabetical and Analytical Index to Transactions, vols. 36-55, inclusive. 1905-1916. New York, 1918.

THE ENGINEER'S YEAR-BOOK OF FORMULÆ, RULES, TABLES, DATA AND MEMORANDA, 1918. Compiled and edited by H. R. Kempe. London, 1918.

GOLD INDUSTRY AND GOLD STANDARD. By Hennen Jennings. (Gift of American Mining Congress.)

PERU, ESTADISTICA MINERA EN 1916. Lima, 1918 (Cuerpo de Ingenieros de Minas del Peru. Boletin No. 86.)

—, INAUGURACION DEL EDIFICIO DEL CUERPO DE INGENIEROS DE MINAS Y AGUAS. (Cuerpo de Ingenieros de Minas del Peru. Boletin No. 88.)

Book Notices

Unless otherwise specified, books in this list have been presented by the publishers. The Institute does not assume responsibility for any statements made; these are taken from the preface or the text of the book, unless otherwise noted.

NORTHWEST MINES HANDBOOK. A Reference Work of the Mining Industry of Idaho, Washington, British Columbia, Western Montana, and Oregon. By Sidney Norman. Vol. I. Spokane, Wash., Sidney Norman, 1918. 366 pp. (advertising pages included), 28 illus., 9 portraits, 2 maps, 13 tab., 10 × 6 in., cloth, \$5.

Covers the mining enterprises which surround Spokane. Contains general descriptive articles on mining and geology of each state, and statistics of production; gives lists of the mines and mining corporations, showing capital stock, property and development.

A HISTORY OF CHEMISTRY. By F. J. Moore, N. Y., McGraw-Hill Book Co., Inc.; Lond., Hill Publishing Co., Ltd., 1918. 14 + 292 pp., 6 illus., 12 pl., 37 portraits, 8 diag., 5 tab., 8 × 6 in., cloth, \$2.50.

This volume is based on a course of lectures given to the senior students of chemistry in the Massachusetts Institute of Technology and is intended to provide a concise account of those facts and influences which have made the science what it is today. Suitable for mature students.

A TEXT-BOOK OF INORGANIC CHEMISTRY. Edited by J. Newton Friend. Vol. V; Carbon and Its Allies, by R. M. Caven, Lond., Charles Griffin & Co., Ltd., Phila., J. B. Lippincott Co., 1917. 21 + 468 pp., 15 illus., 70 tab., 1 chart, 9 × 6 in., cloth.

CONTENTS: Introductory, Carbon and its Compounds, Silicon and its Compounds, Titanium and its Compounds, Zirconium and its Compounds, Thorium and its Compounds, Germanium and its Compounds, Tin and its Compounds, Lead and its Compounds.

The aim of this series is to provide a comprehensive text-book of inorganic chemistry, sufficiently complete for ordinary purposes, and supplied with numerous references to the leading works and memoirs.

HIRING THE WORKER. By Roy Willmarth Kelly. (Industrial Management Library.)

N. Y., The Engineering Magazine Co., 1918. 245 pp., 8 pl., 66 forms, 5 charts, 2 tab., 9 × 6 in., cloth, \$2.

A summary of the efforts of many firms to solve the problems of employment. Describes the theories and policies which have been tested, suggests the possibilities of employment management and attempts to point out the profitable avenues of advancement.

POPULAR OIL GEOLOGY. By Victor Ziegler. Golden, Colo., C. H. Merrifield, 1918. 149 pp., 62 illus., 1 pl., 7 × 5 in., flexible cloth, \$2.50.

An exposition of the fundamental principles of oil geology, intended for men without technical training, who are interested in the subject.

OVER THE DRAWING BOARD. A Draftsman's Hand Book. By Ben J. Lubsch.

Washington, D. C., Journal of the American Institute of Architects, 1918.

10+131 pp., 22 illus., 9 pl., 7 × 5 in., cloth, \$2. (Gift of author.)

CONTENTS: Introductory, Drafting Room, Equipment, Instruments, Mounting of Paper and Drawings, Tracing Paper and Tracing Cloth, Geometrical Short-cuts, Lettering, Tinting, Numbering, Working Drawings, Indications, Lines, Sketches, Exhibition Drawings, Water Colors, Perspective, Filing of Drawings and Plates, Photography, The Reproductive Processes, Photo-Engraving, Etching, Wood Engraving, Lithography.

MINING ENGINEERS' HANDBOOK. By Robert Peele, Editor in Chief, and a board of 43 Associate Editors, New York, John Wiley & Sons, Inc., 1918. 2400 pp., 2000 illus. and numerous tables, 4¼ × 7 in., flexible covers, \$5.

Undoubtedly this is the most important book of reference that has recently been issued for the benefit of mining engineers, and one deserving a far more extended review than space here permits. Not only is space lacking but a competent review could be written only after many hours, indeed after many days, of careful study, and after the reviewer had had an opportunity of using the book for one of the many purposes that the authors had in mind when it was compiled.

Propounding a few mining and metallurgical questions, searching the text, and finding very elaborate or very brief answers as the case may be, one's first thought is that the authors have overdone some phases while omitting or treating too briefly other important matter. Turning back to the preface, however, the engineer will see that Prof. Peele explains satisfactorily why the editors have elaborated upon those features bearing most directly upon strictly mining operations, and why ore-dressing and metallurgy were forced to occupy a less prominent position in the text. The one question that might be raised is whether or not, because of their brief treatment, it would not have been better to have omitted the less relevant subjects entirely. The preface answers this question satisfactorily, and indeed it is impossible to criticise any feature that has not received the careful consideration of the editors during the compilation of the work.

To the man in the field and to the man in the office, questions relating to costs and efficiency are continually presenting themselves, and it is with marked satisfaction that we note in this handbook a serious attempt on the part of the editors to give us data on costs and efficiency with sufficient detail respecting conditions, so that comparisons having real value may be drawn. An estimate upon the cost of recovering metals is difficult at best. When the mine is only partly developed, when no treatment process has been definitely decided upon, when the district is new or remote, the estimate of cost becomes little more than a guess; hence any data bearing on the points involved, data tending to strengthen the guess, are extremely valuable to the engineer.

The elaborate use of references throughout the work will be a cause of great satisfaction to those who may have occasion to consult it. In general, the matter is so well condensed that there will be no occasion for consulting original sources, but the opportunity is wisely given and adds materially to the value of the quotations.

This Mining Engineers' Handbook will sooner or later find itself in the library of every active engineer.

F. F. SHARPLESS.

MEMBERSHIP

NEW MEMBERS

The following list comprises the names of those persons who became members during the period of June 10, 1918, to July 10, 1918.

- ALLPORT, JAMES H., Cons. Engr., Barnesboro, Pa.
 ANDERSON, G. E., Engr., Exploration Dept., American Smelt. & Refin. Co., Tucson, Ariz.
- BAKER, HARRY A., Capt., Co. M, 53d Pioneer Infantry,
 Camp Wadsworth, Spartanburg, S. C.
- BEALL, ROBERT STEPHENS, Supt., Empire Zinc Co. (of Colorado), Canon City, Colo.
- BLAYLOCK, SELWYN GWILLYM, Min. & Met. Engr., Asst. Gen'l Mgr.,
 Cons. Min. & Smelt. Co. of Canada, Ltd., Trail, B. C., Canada.
- BOTTERILL, THOMAS CLARK, Min. Engr., Belmont Surf Inlet Mines, Ltd.,
 Surf Inlet, B. C., Canada.
- BOWMAN, MAURICE, Asst. Supt., New Idria Quicksilver Min. Co.,
 Idria, San Benito Co., Cal.
- BROOKS, EARL W., Chief Engr., Inland Collieries Co., Harmarville, Pa.
- BROWN, DEWITT W., Chief Chem., Prime Western Spelter Co., Iola, Kansas.
- BUISSON, ARTHUR, Min. Engr., Dept. of Mines, Sussex St., Ottawa, Canada.
- BUNTAN, F. W., Chem., Southern Pacific Railway Co., Sacramento, Cal.
- BURNETT, ARCHIBALD, Supt., Swansea Lease Inc., Swansea, Ariz.
- BURTON, GEORGE E., Resident Geol., Empire Gas & Fuel Co.,
 Varsity Shop Bldg., Norman, Okla.
- BUZBY, ARTHUR DUDLEY, 100 Clarewell Ave., Upper Montclair, N. J.
- COLE, JOHN THOMAS, Box 191, Miami, Okla.
- CONCHA, AQUILES S., Director General, Public Works,
 Calle Compania 2473, Santiago, Chile.
- COOK, SPENCER NYE, Gen'l Supt., The Fresnillo Co., Fresnillo, Zacs., Mexico.
- CROWE, JOHN J., Physical Met., Hull Div., Philadelphia Navy Yard, Pa.
- DICKSON, WALTER S., Min. Engr., Charles F. Rand, 71 Broadway, New York, N. Y.
- DRAPER, MARSHALL D., Mgr., Anna Beaver Mine, Tar River, Okla.
- DRULLARD, H. R., Branch Mgr., Denver Rock Drill & Mfg. Co.,
 51 West Granite St., Butte, Mont.
- EDWARDS, EDWARD TUDOR, Vice-pres. & Mgr., Latrobe Electric Steel Co., Latrobe, Pa.
- ELLIOTT, J. E., Chief Geol., Shell Co. of California, 343 Sansome St.,
 San Francisco, Cal.
- FINK, COLIN GARFIELD, Director of Research Laboratories, Chile Exploration Co.,
 202d St. & 10th Ave., New York, N. Y.
- FITZ-WILLIAM, G. L., Chem. Met. & Min. Engr., Research & Examinations,
 Indiana Laboratories Co., Inc., Hammond, Ind.
- FRITH, CHARLES WILLIAM, Met. Engr., 3d Co. Coast Artillery Corps, San Pedro, Cal.
- GUDKOV, VALENTIN JOHN, Room 1404, 32 Court Street, Brooklyn, N. Y.
- GROUT, FRANK F., Associate Prof., Geol. & Mineralogy,
 University of Minnesota, Minneapolis, Minn.
- HALL, DURAND APPLETON, Min. Geol., U. S. Shipping Board,
 4226 New Interior Bldg., Washington, D. C.
- HALLECK, PHILO HALSIA, City Engr., Bisbee, Ariz.
- HALLINGBY, O., Supt., LaSalle Copper Co., Calumet, Mich.
- HARTZELL, H. H., Supt. of Mines, S. Y. Ramage, Lock Box 265, Joplin, Mo.
- HIRSH, RALPH T., 19th Co. C. A. C., S. N. Y., Ft. Hamilton, N. Y.
- HOLMES, THOMAS B., Supt., American Graphite Co., Graphite, N. Y.
- HOLMLIN, CARL A., Mine Supt., Nevada Packard Mines Co., Lower Rochester, Nev.
- HOLMQUIST, GUSTAVE S., Min. Engr., Ordnance Dept., Washington, D. C.
- HOLSTEIN, GEORGE M., Mgr., William P. Clyde, 61 Broadway, New York, N. Y.
- HOOK, CHARLES R., Vice-pres. & Asst. Gen'l Mgr.,
 The American Rolling Mill Co., Middletown, Ohio.
- HULL, J. P. D., Asst. State Geol., Atlanta, Ga.
- HYDER, FREDERICK BOREN, Geol., Thane Exploration Dept., 408 Crocker Bldg.,
 San Francisco, Cal.

JACKS, MASTON EDWARDS.....Met., Calumet & Arizona Min. Co., Douglas, Ariz.
 KINDSETH, GRAHAM M.....Testing Engr., International Smelt. Co., Miami, Ariz.
 KWASHA, GEORGE.....59 West 104th St., New York, N. Y.
 LENNOX, LUTHER W., Asst. Supt., Milling Dept.,
 The Portland Gold Min. Co., Victor, Colo.
 LEONARD, C. M., Supt. of Mines, E. I. du Pont de Nemours & Co.,
 Church Bldg., Wilmington, Del.
 McLEOD, A. B.....Mine Supt., Butte & Superior Min. Co., Butte, Mont.
 MATSON, GEORGE CHARLTON, Chief Geol., Gypsy Oil Co.,
 Room 410, Clinton Bldg., Tulsa, Okla.
 MAUCH, JOHN L., Engr. in Charge of Design of Caletones Smeltery,
 Braden Copper Co., 120 Broadway, New York, N. Y.
 MAVERICK, PHILLIP, Chem., Washoe Reduction Wks.,
 Anaconda Copper Min. Co., Anaconda, Mont.
 MERIWETHER, MINOR, Pet. Engr. & Asst. to Executive,
 Mid-Co. Petroleum Co., Tulsa, Okla.
 MILLER, AUBREY C., Met. Chem., Granby Cons. Min. Smelt. & Power Co.,
 Ltd., Anyox, B. C., Canada.
 MOLL, C. D.....Camp Wheeler, Macon, Ga.
 MOORE, RICHARD B., Supt., Colorado Station, U. S. Bureau of Mines, Golden, Colo.
 NAKAYE, SEIZO.....348 Tomikoji, Ebeugawa, Kyoto City, Japan.
 NASH, HOWARD F.....Geol., Empire Gas & Fuel Co., Bartlesville, Okla.
 NEGRU, JACQUES S.....Pte. 2504000, Railway Constr. Corps, C. E. F.
 NEWTON, FRANK B., Min. Engr.....First National Bank Bldg., Carthage, Mo.
 PARMELEE, JAMES G.....University of Idaho, Moscow, Ida.
 REES, CHARLES, Supt., Ramapo Ore Co., Inc., Sterlington, Rockland Co., N. Y.
 REESE, ARTHUR G.....Mech. Engr., Wellman Seaver Morgan Co., Cleveland, Ohio.
 REINTJES, W. J.....Min. Engr., Vandalia Coal Co., Linton, Ind.
 ROBITAILLE, A. EDMOND.....Pet. Geol., 209 Lynch Bldg., Tulsa, Okla.
 ROOB, ALFORD, Pres. & Gen'l Mgr., Pima Smelting Co., 37 So. Stone Ave.,
 Tucson, Ariz.
 SHEARER, HAROLD K.....Asst. State Geol., State Capitol, Atlanta, Ga.
 SPENCER, MARSHALL G., Asst. Supt. of Foundry, Watertown Arsenal,
 Watertown, Mass.
 STEINEM, CHESTER.....2228 Scottwood Ave., Toledo, Ohio.
 STOCKETT, B. H.....Gen'l Supt., Locust Mountain Coal Co., Shenandoah, Pa.
 STONE, FRED W., Min. Engr., Diamond Drill Contracting Co.,
 429 First Ave., Spokane, Wash.
 SWANSON, E. R., Capt., Ordnance Dept., 6826 Fifth St., N. W., Washington, D. C.
 TANDY, CHARLES W., JR., Designing Engr., Anaconda Copper Min. Co.,
 Great Falls, Mont.
 TEMPLETON, EUGENE C., Co. C, 27th Engineers, A. E. F., Care Postmaster, N. Y.
 THOMAS, KARL B., Chem. Engr., Supt., Sulphuric Acid Dept.,
 Calumet & Arizona Min. Co., Douglas, Ariz.
 TOYODA, HIDEKANE.....The Kune Mine, Iwatagun, Shizuokaken, Japan.
 WAHL, HENRY R., Engr. & Designer, Phillips, Lang & Co., Fisher Bldg., Chicago, Ill.
 WHYTE, W. CAMPBELL, Sec'y, The Steel Improvement & Forge Co., Cleveland, Ohio.
 WILKE, WILLIAM, JR.....Sec'y & Treas., Metals Refining Co., Hammond, Ind.
 YOUNG, WILLIAM G., Cons. Geol. & Min. Engr.....Ocean Park, Cal.

Associates

ADAIR, ARTHUR C., Min. Engr., Crystal Coal & Coke Co., Crystal,
 Mercer Co., West Va.
 APPLIN, PAUL L.....Geol., Roxana Petroleum Co. of Oklahoma, Tulsa, Okla.
 BACH, EDWIN EMMET, Sociological Director, Ellsworth Collieries Co., Ellsworth, Pa.
 CORBETT, WILLIAM J., 1st Lieut., Ordnance Reserve Corps, U. S. Army,
 Watertown Arsenal, Watertown, Mass.
 GITLAN, CHARLES, Sec'y Wahchang Trading Corp., 49th Floor, Woolworth Bldg.,
 New York, N. Y.
 GOWLING, THOMAS A.....Exploring Engr., E. J. Longyear Co., Minneapolis, Minn.
 HAYES, REESE LEONARD, Co. 56, Bat. 14, 165th Depot Brigade, N. A.,
 Camp Travis, Texas.
 KROEGER, ADOLPH C., Min. Engr., Co. A, 14th Infantry, Fort Seward, Haines, Alaska.
 MUSSELMAN, CLAUDE EDWARD, Min. Geol., Vinegar Hill Zinc Co., Platteville, Wis.

- SCHUETTE, CURT N., Min. Engr., U. S. Bureau of Mines, New Idria & Oceanic
Quicksilver Mines, 930 Broderick St., San Francisco, Cal.
SIMPSON, GEORGE N., Gen'l Mgr. & Sec'y, Wood Equipment Co.,
McCormick Bldg., Chicago, Ill.
STROUD, J. E. C., Met. Chem., Granby Cons. Min., Smelt. & Power Co., Ltd.,
Anyox, B. C., Canada.
WATSON, ALEXANDER, Asst. Treasurer, Wah Chang Trading Corp., Room 4903,
Woolworth Bldg., New York, N. Y.

Junior Associates

- AMIDON, CLAUDE E. Student, Colorado School of Mines, Golden, Colo.
ARMSTRONG, HAROLD KERR Student Pilot, Naval Aviation.
BEVAN, JOHN G. Student, Colorado School of Mines, Golden, Colo.
BUNTE, ERNEST B. 1277 Downing St., Denver, Colo.
CASE, WILLIAM B. Student, Colorado School of Mines, Golden, Colo.
COWIN, PERCY G., Flying Cadet, U. S. School of Military Aeronautics,
Barracks No. 2, Urbana, Ill.
JOHNSON, ROSCOE P. Student, Colorado School of Mines, Golden, Colo.
LINN, HERBERT KARL Student, Colorado School of Mines, Golden, Colo.
MACDONALD, CHARLETON E., Chem., Canadian Copper Co., Copper Cliff,
Ont., Canada.
MARA, HUBERT W. Student, So. Dakota School of Mines, Rapid City, So. Dak.
MECHIN, RENE J. Student, Colorado School of Mines, Golden, Colo.
NELSON, AXEL S. Asst. Min. Engr., East Butte Copper Co., Butte, Mont.
NUFIO, GUSTAVE ADOLFO, Min. Engr., Government of Honduras, Danli,
Honduras, C. A.
PYBURN, PAUL F. JR. 1094 Dean St., Brooklyn, N. Y.
REITH, LINDLEY M. Asst. County Surveyor, Yolo Co., Cal.
SISSON, M. L. Student, Colorado School of Mines, Golden, Colo.
TSEN, B. C. Student, Colorado School of Mines, Golden, Colo.

Change of Status—Junior Associate to Member

- LUERSSSEN, GEORGE V., 2d. Lieut., Ordnance R. C., Watertown Arsenal,
Watertown, Mass.
RUEBEL, E. H. Chief. Chem., National Zinc Co., Springfield, Ill.
SCHMIDT, WILLIAM C., Co. F, 1st Replacement Regiment Engrs.,
Washington Barracks, D. C.
SCOLES, JOHN C., Min. Engr., Mines Efficiency Co., 708 Alworth Bldg., Duluth, Minn.

Change of Status—Junior Associate to Associate

- BLOGG, CECIL F. Smoke Chem., Tacoma Smelt. Co., Tacoma, Wash.
BURRAGE, ROBERT H. 1st Lieut., 27th Engineers, N. A., Camp Meade, Md.
Total Membership, July 10, 1918. 6865

CANDIDATES FOR MEMBERSHIP

APPLICATION FOR MEMBERSHIP.—The Institute desires to extend its privileges to every person to whom it can be of service. On the other hand, it is not desirable that persons should be admitted to membership in classes for which they are not qualified. Members of the Institute can be of great service, if they will make a practice of glancing through the list of applicants and promptly notifying the Committee on Membership, or the Secretary of the Institute, of any persons whom they think should not be classified in accordance with the list given.

Applications Lacking Endorsement

Applications for membership have been received from Mr. Hogg, Mr. Schuler, Mr. Teale and Mr. Wilkie, whose records are given below.

These applications lack the necessary number of endorsers, but since these candidates live at some distance from the headquarters of the Institute, their records are published here in order that any members who are acquainted with them may be advised of the circumstances and may have an opportunity of writing to the Secretary endorsing these candidates.

Members

James Hogg, Euboea, Greece.

Proposed by P. D. Ahier.

Born 1871, Lanarkshire, Scotland. Hutchesontown Grammar School, Glasgow. Glasgow Technical College. Member, Institute of Min. and Met. and Federated Institute of Min. Engrs. 1890-95, Min. Apprentice, McCreaths & Stevenson, Glasgow. 1895-97, Underground Colliery Mgr., Podmore Hall Collieries, Staffordshire. 1897-1904, Mines Mgr., Aznalcollar Mines, Seville Sulphur & Copper Co., Seville, Spain. 1904-11, Mgr., Heredia Lead Mines, Linares, Spain. 1911-17, Mgr., Anglo-Greek Magnesite Co., Ltd.

Present position: Director and Mgr., Anglo-Greek Magnesite Co., Ltd.

Herman Schuler, Vallenar, Chile.

Proposed by Philip R. Gleason, John P. Chadwick.

Born 1878, Schaffhouse. 1898, Grad., Lyceum of Winterthur, Switzerland. 1902, Grad., Polytechnical School of Zurich, Switzerland, C. E. 1902-04, Civil engr., Swiss Govt. 1904-06, With Harkort Co., steel construction, Duisburg, Germany. 1906-07, Hydraulic work in Silesia for German Govt. 1907-09, Min. Engr., Naltagua Copper Co., Chile. 1909-12, Railroad constructor for Chilian Govt.

Present position—1912 to date: Mine Operator, Vallenar Dist.

Donald Cook Wilkie, Serembau, Federated Malay States.

Proposed by

Born, 1879, Dundee, Scotland. Brothers' school, Penang, Straits Settlements; Baptists' School, Rangoon, Burmah; Donaldson's School, Dundee, Scotland; 1890-92, Wallacetown School, Dundee, Scotland. 1892-98, Mechanical and electrical construction and repair work; engr. experience; drafting room; shop at sea, Ross & Wilkie, Scotland. 1898-99, Asst. Engr., China Borneo Co., Ltd., Sandakan, B. N., Borneo. 1901-03, Salvage Dept., Tangong Pagar Dock Co., Ltd., Singapore. 1903-10, Engr., Pyritical Ore Installation, Sungei Besi recovery of tin stone from arsenical and sulphurous ores, The Straits Trading Co., Ltd., Sungei Besi, Malay States.

Present position—1910 to date: Supt. Engr., Linggi Plantations Ltd.

Associate

James Willie Teale, Euboea, Greece.

Proposed by P. D. Ahier.

Born 1882, Leeds, England. 1886-90, General education, Leeds School Board. 1890-95, Ossett School, near Wakefield. 1895-1902, Ossett Technical School, full engr. course, science and art, South Kensington, obtaining Advanced Certificates. Correspondence courses. 1898-1903, Apprenticed to Bradley & Craven, Ltd., Engrs., Iron & Brass Foundries, Wakefield, England. 1904-06, Asst. to mech. and elec. engr., Old Roundwood Collieries, Wakefield, England. 1907, Asst. to mech. and elec. engr., Hoyland Lilkstone Collieries, Ltd., Barnsley. 1908, Asst. to mech. and elec. engr., Bulcroft Main Collieries, Doncaster, England.

Present position: Mech. Engr., The Anglo-Greek Magnesite Co., Ltd.

The following persons have been proposed during the period June 10, 1918, to July 10, 1918, for election as members of the Institute. Their names are published for the information of Members and Associates, from whom the Committee on Membership earnestly invites confidential communications, favorable or unfavorable, concerning these candidates. A sufficient period (varying in the discretion of the Committee, according to the residence of the candidate) will be allowed for the reception of such communications, before any action upon these names by the

Committee. After the lapse of this period, the Committee will recommend action by the Board of Directors, which has the power of final election.

Members

Homer Custer Althar, Bellaire, Ohio.

Proposed by Harry A. Lynch, S. J. Kidder, D. B. Scott.

Born 1887, St. Clairsville, O. 1905, Public schools, Bellaire, O. 1905-07, Private study, chem. 1907-12, Private study, min. engr. 1905-07, Asst. Chem., Bellaire Works, Carnegie Steel Co. 1907-09, Transitman, A. J. Harbaugh, Bellaire, O. 1909-10, Asst. County Engr., Belmont Co., O. 1910-13, Engr., construction of transmission lines and sub-stations, Sunnyside Electric Co., Wheeling, W. Va.

Present position—1913 to date: Min. Engr., The Lorain Coal & Dock Co., Columbus, O.

Henry M. Ami, Washington, D. C.

Proposed by A. F. Lucas, P. N. Moore, David White.

Born 1858, Belle Rivière, Canada. 1882, Grad., McGill Univ., B. A. 1885, M. A. 1907, D. Sc. 1892, Queens Univ., D. Sc. Special and honor work in geol. 1882-1912, On staff of Geological Survey of Canada. Member of Canadian Mining Institute since inception; Fellow of geological societies in London, France, America, Switzerland, etc., etc. Vice-Pres., Société Géologique de France, Paris, 1918. 1883-1918, Geol. work in field in coal, petroleum, natural gas, salt, gypsum and other areas. 1903, Canadian Government Report, "Natural Resources along the Line of the National Transcontinental Railway from Quebec to Winnipeg." 1915, "Canada and Newfoundland," Stanford's Compendium of Geography and Travel with geol., min. resources, etc. of British North America, 1069 pages. 1882-1915, Many publications relative to geol., stratigraphy, economic (mineral and other) resources of Nova Scotia, Quebec, Ontario, British Columbia.

Present position: On Volunteer Staff, British Embassy, War Metals and Minerals.

John T. Baker, Phillipsburg, N. J.

Proposed by P. W. Shimer, Joseph W. Richards, Edward Hart.

Born 1860, Orange, N. J. 1882, Grad., Lafayette College, B. S.; 1885, M. S. 1882-84, Manufacture of chemical reagents, Easton, Pa. 1884-96, Manufacture of chemical reagents, Baker & Adamson, Easton, Pa. 1896-1904, Officer and Director, Baker & Adamson Chemical Co., Inc., Easton, Pa.

Present position—1904 to date: Pres. and Gen'l Mgr., J. T. Baker Chemical Co.; 1911 to date, Editor, *The Chemist-Analyst*, published by J. T. Baker Chemical Co.

Reginald Leighton Chase, Denver, Colo.

Proposed by William J. Cox, Charles A. Chase, Frank E. Shepard.

Born 1889, Central City, Colo. 1907-11, Univ. of Colorado, special engr. course. 1912-13, Engr., Tri-Bullion Smelt. & Development Co., Kelly, New Mexico. 1913-14, Engr.; Asst. Supt., Woolton Land & Fuel Co., Woolton, Colo.

Present position—1914 to date: Min. Engr. and U. S. Min. Surveyor, private practice, Edwin E. Chase & Son.

Charles Albert Cheney, Crosby, Minn.

Proposed by Holman I. Pearl, Ben A. Mizzen, C. K. Leith, O. W. Wheelwright.

Born 1885, Madison, Wis. 1909, Grad., Wisconsin Univ., B. S. 1908, Exploration work, Mich., under Prof. C. K. Leith. 1909-11, Exploration and geol., Northwestern Improvement Co., Cuyuna Range, Minn. 1911-12, Geol., E. J. Longyear Co., Mich. and Minn. 1912, Geol., Northwestern Improvement Co., Cuyuna Iron Range. 1912-13, Geol., E. J. Longyear Co., Wis., Mich., Ark. 1913-14, Geol., Minnesota Survey. 1914-15, Consulting work, Mich., Wis., Minn. Publications: "Structure of Cuyuna Iron-Ore District of Minnesota," "What the Dip Needle Can and Cannot Do."

Present position—1915 to date: Geol., George H. Crosby, and Supt., Crosby Exploration Co.

John William Crowds, El Paso, Tex.

Proposed by David Cole, Julius Bergman, W. R. Palmer.

Born 1884, Dallas, Tex. 1904, Grad., Virginia Military Institute. 1905, Grad., Michigan College of Mines, B. S. 1906, Asst. Engr.; Engr., Burro Mountain Copper Co., Leopold, N. M. 1906-07, Ch. Engr. and Supt. of Construction, Comanche Min. & Smelt. Co., Silver City, N. M. 1907, Supt., Providencia mine, Silver City, N. M.

1907-08, Levelman, United States Reclamation Service, Elephant Butte Project, Engle, N. M. 1908, Ch Engr., Dawson Min. Co., Nacozari, Sonora, Mex. 1909-12, Engr., Mill Operator, Supt. of Construction, Mill Supt., Socorro mines, Mogollon, N. M. 1912-13, Supt. of Construction, Cinco Minas, Hostotipaquillo, Jalisco, Mex. Present position—1914 to date: Cons. Engr., El Paso, Tex.

Jack Henry Foran, Sumatra, D. E. Indies.

Proposed by Gilmour E. Brown, George E. Stott, N. L. Wimmier.

Born 1884, Eastbourne, England. 1894-1900, Private schools. 1900-01, Elizabeth College, Guernsey. 1901-03, Brighton School of Engineering. 1903-05, School of Mines, Camborne, England. 1908, Student. 1911, Associate, Institution Min. and Met., London. 1905-10, Various positions and Assayer, Redjang Lepong mine, Sumatra. 1911-14, Assayer and Gen'l Asst. to Mgr., Kinandam mine, Sumatra. 1914-17, On Exploration Staff, Maatschappij tot Myn, Bosch en landbouw exploitatie in Langkat.

Present position: Min. Engr., Maatschappij tot Myn, Bosch en landbouw exploitatie in Langkat.

Ralph Roy Knowles, Ouray, Colo.

Proposed by C. R. Wilfley, G. H. Barnhart, R. B. Morton.

Born 1875, Osage, Iowa. 1894-99, Worcester Polytechnic Institute, B. S. 1899-1900, Supt., Idaho Springs Electric Light, Power & Heating Co., Idaho Springs, Colo. 1900-01, Millman, Bostonian Min. & Mill. Co., Black Hawk, Colo. 1901-02, Master Mechanic, Golden Smelter, Golden, Colo. 1902-03, Engr., Merino Valley Dredging Co.; Mgr., Fraser Mt. Copper Co., New Mexico. 1903-04, Asst. Master Mech.; Elec. Engr., American Smelt. & Refin. Co., Leadville, Colo. 1904-05, Elec. and Cons. Engr., Yak Tunnel Co., Leadville, Colo. 1905-06, Master Mech.; Supt. Construction, Gunnison Tunnel, Montrose. 1906-11, Supt., Newhouse Tunnel, Idaho Springs, Colo. 1911-17, Instructor, Elec. Engrg.; Instructor, Min. Engrg. 1912-16, Instructor, Physics. 1916-17, Instructor, Mech. Engrg., Colorado School of Mines, Golden, Colo. 1911-16 (Summers), Efficiency Engr., min., mill. and engr. propositions; mine examinations and reports.

Present position: Supt., Ouray Consolidated Min. & Reduction Co.

Stanley Martin, Kingston, Pa.

Proposed by H. S. Drinker, H. Eckfeldt, C. Dorrance, Cadwallader Evans, Jr.

Born 1890, Edwardsville, N. Y. Lehigh Univ., Coxe School of Mines. 1903-11, Practical min. experience, Kingston Coal Co., Kingston, Pa. 1912-16, Summer work on engr. corps, Lehigh Valley Coal Co., Wilkes-Barre, Pa. 1916-17, Student, Course in Min., Delaware & Hudson Co. 1917-18, Asst. Foreman, Coal Brook Colliery, Delaware & Hudson Co.

Present position: Transportation Inspector, Hudson Coal Co.

Thomas Sheppard Mennie, Cobalt, Ont., Canada.

Proposed by T. R. Finucane, Arthur A. Cole, H. A. Kee.

Born 1873, Mt. Forest, Ont. Educated at Ishpeming and Bessemer public schools, Mich. 1892-95, Concentrator Millman. 1895-1900, Shift Boss, Colusa Parrot Min. & Smelt. Co., Butte, Mont. 1900-01, Mill Supt., Ray Copper Mines, Ltd., Kelvin, Ariz. 1901-02, Mill Supt., Rock Lake Min. Co., Bruce mines, Ont. 1902-05, Millman; 1905-11, Shift Boss, Colusa Parrot Min. & Smelt. Co., Butte, Mont. 1911-13, Mill Supt., City of Cobalt Min. Co., Cobalt, Ont. 1913-14, Shift Boss, McKinley-Darragh-Savage Mines of Cobalt, Ltd., Cobalt, Ont.

Present position—1914 to date: Mill Supt., McKinley-Darragh-Savage Mines of Cobalt, Ltd.

Floyd Calhoun Merritt, Challis, Idaho.

Proposed by F. A. Linforth, Reno H. Sales, G. A. Joslin.

Born 1889, Pomona, Cal. Grammar and high schools. 1906-10, Leland Stanford Junior Univ., A. B. 1910-12, Geol., Anaconda Copper Min. Co., Butte, Mont. 1912-13, Geol., Caribbean Petroleum Co., Caracas, Venezuela, S. A. 1914-17, Engr., California Highway Commission, Div. V, San Luis Obispo, Cal.

Present position—1917 to date: Supt., Ramshorn Mine, Aetna Min. & Investment Co.

Charles Andrews Miller, Jerome, Ariz.

Proposed by O. V. Hopkins, Robt. E. Tally, H. DeWitt Smith.

Born 1873, Birmingham, Iowa. 1891, Public schools. 1892, Throop Polytechnic

School. 1893, Grad., Business College. 1906-09, Miner. 1909-11, Caring for ore shipments. 1911-15, Geol., United Verde Copper Co.

Present position—1915 to date: Asst. Min. Supt., United Verde Copper Co.

John Flickinger Myers, Canon City, Colo.

Proposed by Arthur Thatcher, Russell B. Paul, Arthur J. Hiester.

Born 1889, New London, Wis. 1913, Colorado School of Mines, E. M. 1913-14, Flotation Engr. Asst., Butte & Superior Copper Co., Butte, Mont. 1914-15, Charge of flotation plant, American Zinc, Lead & Smelt. Co., Mascot, Tenn. 1915-17, Flotation Engr., New Jersey Zinc Co., New York, N. Y.

Present position—1917 to date: Charge of Testing Plant, Empire Zinc Co., Canon City, Colo.

Clive W. Newcomb, Antofagasta.

Proposed by Thomas C. Peddar, Lester W. Strauss, J. Inch.

Born 1886, London, England. Askes Hatcham, London; Upper Latymer, Chiswick, London. Asst. Gen'l Mgr., Progreso Co., Oficinas Ansonia Filomena Acanagua.

Present position: Mgr., Oficina Santa Santa Rosa; Mgr., Oficina Carmela Fortuna Nitrate Co., Gibbs & Co., Agents.

Liphe Andrews Osborn, Welch, W. Va.

Proposed by Thomas H. Clagett, Henry W. Saunders, Howard N. Eavenson.

Born 1880, Columbus, Ohio. Eight years common schools; three years high school, Columbus, O. Four years, Ohio State Univ. 1902-03, Engr. corps and office, Shawmut Min. Co., Shawmut, Pa. 1903, Engr., Crooked Fork Coal & Coke Co., Petros, Tenn. 1904-10, Contracting engr. office, Jellico, Tenn. 1910-12, Supt., Asher Coal Min. Co., Wasioto, Ky. 1912, Engr., Middle States Coal & Coke Co., Huger, W. Va. 1913-14, Engr. office, United States Coal & Coke Co., Gary, W. Va. 1915-16, Engr., Crystal Block Coal & Coke Co. 1917-18, Contracting engr. office, Welch, W. Va.

Present position: County Surveyor, McDowell Co., West Va.; City Engr., Welch, W. Va.

L. J. Rosenshine, San Francisco, Cal.

Proposed by Charles Butters, James M. Platt, H. A. Barker.

Born 1886, San Francisco, Cal. 1906-10, Univ. of California, B. S. 1910-11, Practical mill and mine experience, Bunker Hill & Sullivan mine, Idaho. 1912-13, Minas del Tajo and La Palma, Sinaloa, Mex. 1913-15, Bluestone mine, Mason, Nev. 1916-17, Montana Mines Co., Ruby, Ariz. 1917, Flotation experimental work. Charles Butters & Co., Oakland, Cal.

Present position: Mill Supt., Sociedad Esplotadora de Coylloma Consolidada, Arequipa, Peru.

Maynard J. Trott, Colorado Springs, Colo.

Proposed by A. L. Blomfield, L. S. Harner, G. W. Taylor.

Born 1882, Wilmington, Ill. 1908, Grad., Colorado School of Mines, E. M. 1906, Chem. Assayer, Old 100 Min. Co., Howardsville, Colo. 1908-13, Chem.; 1913-15, Night Supt. of Mill, Golden Cycle Min. Co., Colorado Springs, Colo.

Present position—1915 to date: Asst. Supt., Golden Cycle Min. Co.

Charles Henry Warner, Valedon, New Mexico.

Proposed by Alvin B. Carpenter, A. B. W. Hodges, F. B. Close.

Born 1872, Clinton, Wis. High school, Beloit, Wis. 1880-1903, Draftsman and designer, Beloit Iron Works, Beloit, Wis. 1903-12, Designer and manufacturer, magnetic speed indicators, Warner Instrument Co., Beloit, Wis.

Present position—1907 to date: Sec'y and Director, "85" Min. Co., Lordsburg, N. M.

Frank Maxwell Wichman, Salt Lake City, Utah.

Proposed by Edward K. Judd, Ernest Gayford, W. A. Wilson.

Born 1881, Montclair, N. J. Montclair public schools. 1899-1903, Columbia Univ. School of Mines. 1902 (Summer), Practical underground work, Park City, Utah. 1904, Practical mill work, Park City, Utah. 1905, Practical mill work, Newhouse, Utah. 1905-06, Min. Engr., Utah & Eastern Copper Co., Dixie, Utah. 1906-09, Min. Engr. 1909-10, Mill Supt., Bingham-New Haven Copper & Gold Min. Co., Bingham, Utah. 1910-16, Supt. of Mines, Bingham-New Haven Copper &

Gold Min. Co. and Utah Metal & Tunnel Co. 1916, Operating Lease, Oustomah mine, Nevada City, Cal. 1917-18, Cons. Engr., Utah Metal & Tunnel Co., Bingham, Utah.

Present position: Member firm, Bauchelle & Wichman, Managing Engr., Utah Metal & Tunnel Co.

Alan Dean Wilkinson, Cananea, Sonora, Mexico.

Proposed by M. J. Elsing, F. J. Strachan, G. W. Prince.

Born 1885, Fort Meade, S. D. 1907, Grad., Ohio State Univ., E. M. 1908-14, Met. Chem., Field Engr. in charge of construction, and various metallurgical, engineering and experimental capacities, American Smelt. & Refin. Co., El Paso, Tex.

Present position—1914 to present: Asst. Smelter Supt., Cananea Consolidated Copper Co., smelting works.

Associates

Ray Cook Ahnefeldt, Socorro, New Mexico.

Proposed by C. A. Schmidt, S. Ringlund, Cony T. Brown.

Born 1892, Menominee, Mich. 1910, High School, Riverside, Cal. 1913-18, New Mexico School of Mines, B. S. Min. Engr., B. S. Civil Engr. 1910-13, Dairyman, Riverside, Cal. 1915-16, Construction Foreman, New Mexico School of Mines. 1916-18, Stationary Oil Engine Operator, New Mexico School of Mines. 1917, Topographer, Empire Zinc Co.

Present position: 2d Lieutenant, Engr., United States National Army, Camp Lee, Petersburg, Va.

Fisher A. Buckingham, San Francisco, Cal.

Proposed by Selden S. Rogers, Bayard S. Morrow, Robert W. Handley.

Born 1893, San Francisco, Cal. 1908-12, Lowell High School, San Francisco, Cal. 1913-17, Univ. of California, B. S.

Present position—1917 to date: Research work on flotation reagents, Standard Oil Co. of California.

William Benjamin Gero, East Orange, N. J.

Proposed by G. H. Cox, D. H. Radcliffe, Alfred G. Heggem.

Born 1892, Malone, N. Y. 1908-12, Franklin Academy, Malone, N. Y. 1912-16, Clarkson Memorial College of Technology, Potsdam, N. Y., B. S. 1914-15 (Summers), Engr. Dept., New York State Highway Commission.

Present position—1916 to present: Chem. Engr., research on and manufacture of tungsten and molybdenum products, Westinghouse Lamp Co., Bloomfield, N. J.

Andrew Nicholls Mackenzie, Bartlesville, Okla.

Proposed by J. C. Branner, C. F. Tolman, Jr., Welton J. Crook.

Born 1888, Los Angeles, Cal. 1905-09, Grad., Polytechnic High School, Los Angeles, Cal. 1909-10, Civil Engrg., Univ. of Southern California, Los Angeles, Cal. 1911-12, Civil Engrg.; Throop College of Technology, Pasadena, Cal. 1912-16, Geol., Leland Stanford Univ., Palo Alto, Cal. 1909 (Summer), Chain, level- and transitman, Pacific Telephone & Telegraph Co., Los Angeles, Cal. 1910 (Summer), Cable Dept. 1910-11, Supply Dept., Pacific Telephone & Telegraph Co., Riverside, Cal.

Present position—1916 to date: Oil Geol., Empire Gas & Fuel Co.

James T. Wood, Jr., Camp Fremont, Cal.

Proposed by C. F. Tolman, Jr., W. F. Dietrich, Welton J. Crook.

Born 1895, White Sulphur Springs, Mont. 1914, Grad., High school, Palo Alto, Cal. 1914-18, Stanford Univ., A. B. 1913, 1914, Asst. to County Engr., Meagher Co., Mont. 1917, Topographer, Santa Cruz Military Survey; Asst. to Prof. C. F. Tolman, Jr., Foothill Copper Belt, Cal.

Present position: 4th Officers Training Camp.

Junior Associates

Edward Rahr Borchardt, Houghton, Mich.

Proposed by Albert J. Houle, J. B. Cunningham, F. W. Sperr.

Born 1894, Davenport, Iowa. 1909-13, High School, Davenport, Iowa. 1913-16, Univ. of Michigan. 1916-17, Michigan College of Mines. 1917-18, Engr., O. M. Bilharz Min. Co.

Present position: Student, Michigan College of Mines.

Albert Henry Kiesel, Ouray, Colo.

Proposed by Harry J. Wolf, J. C. Williams, I. A. Palmer.

Born 1895, Ouray, Colo. 1911-15, High school, Ouray, Colo. 1915-17, Colorado School of Mines. 1917, Tonopah-Belmont Co., Alta mine; Atlas Min. & Mill. Co., Ouray, Colo.; Ouray Consolidated Min. & Reduction Co., Ouray, Colo. 1917-18, Head of Science Dept., Ouray High School, Ouray, Colo.

Present position: Student, Colorado School of Mines.

Homer Coté, Rocksprings, Wyo.

Proposed by Arthur C. Terrill, B. L. Wolfe, Erasmus Haworth.

Born 1885, Kansas. 1913-17, Univ. of Kansas, B. S. 1900-07, Coal min., Southeast, Kansas. 1907-10, Coal min., Arkansas. 1910-13, Metal min., Joplin, Mo.

Present position: Engr. Dept., Union Pacific Coal Co., Rocksprings, Wyo.; International Smelt. Co., Tooele, Utah.

MEMBERS' ADDRESSES WANTED

Name.	Last address of Record from which Mail has been returned.
ASHMORE, ERNEST P.	504 Sherbourne St., Toronto, Ont., Canada.
BARNARD, C. W.	North Chicago Hospital, 2551 N. Clark St., Chicago, Ill.
BARNETT, WILLIAM J.	8 Waterloo Place, Pall Mall, London, S. W., England.
BOAS, ROSS H.	Highland Boy Mine, Bingham Canyon, Utah.
BROOKE, LIONEL.	Minas del Tajo, Rosario, Sinaloa, Mexico.
BROWNE, ARTHUR B.	Care Malleable Iron Fittings Co., Branford, Conn.
BRYANT, GEORGE W.	Apartado 86, Guanajuato, Mexico.
ARMSTRONG, HAROLD KERR,	Student Flight Officer, U. S. Naval Reserve Flying Corps, Dunwoody Naval Training Station, Minneapolis, Minn.
BATCHELLER, J. H.	Mattapoisett, Mass.
BAUMGARTEN, K., 1st Lieut., 1st Corps Schools,	A. P. O. 703, A. E. F., France.
BAYLESS, G. E. S.	Supply Dept., U. S. Submarine Base, New London, Conn.
BEARD, JOHN W.	Cia Minera de Penoles, Ojuela, Dgo., Mexico, via Mapimi.
BELL, ALAN D.	Tecumseh, Mich.
BENSEL, J. A.	Major, Board of Control, 254 Granby St., Norfolk, Va.
BERG, HASKON A., Asst. Supt., Carrie Furnaces,	Carnegie Steel Co., Rankin, Pa.
BILLYCK, DON C.	Co. C, Ordnance Supply School, Camp Hancock, Augusta, Ga.
BILLINGSLEY, PAUL, 1st Lieut., N. A. Statistics Branch,	General Staff, Room 808, Mills Bldg., Washington, D. C.
BONSIB, R. S., District Safety Engr., U. S. Emergency Fleet Corp.,	310 Sansome St., San Francisco, Cal.
BORNHOFT, HENRY.	Apartado 1263, Mexico D. F., Mexico.
BOWMAN, F. C.	1522 West Eighth Ave., Spokane, Wash.
BOWMAN, J. V.	Instructed to hold everything.
BOYD, A. W.	W. 933 17th Ave., Spokane, Wash.
BRANDES, JUAN F.	Box 242, Santa Barbara, Cal.
BROKAW, ALBERT DUDLEY, Petroleum Expert, U. S. Shipping Board,	Washington, D. C.
BROOKS, CHARLES A.	Recruit Detachment, 27th Engineers, Camp Meade, Md.
BROWN, LOWELL H., Capt., Signal Reserve Corps, Aviation Section,	War Dept., Spruce Production Div., South Beach, Ore.
BRUNEL, LOUIS J.	Lieut., U. S. Army, A. E. F., Care Postmaster, N. Y.
CADOT, J. J., 1st Lieut., Signal Reserve Corps, Aviation Section, Camp Dick,	Dallas, Texas.
CASTLETON, WILLIAM A.	3233 Hunter Boulevard, Seattle, Wash.
CHALMERS, THOMAS S.	Major, Ordnance, N. A. A. E. F., Care Postmaster, N. Y.
CHAPMAN, ROBERT H.	Major, Engr. R. C., Headquarters Eastern Dept.
CHASE, LYSLE, No. 2011205, Engineers Training Depot, St. John's, P. Q., Canada.	
CHETNEY, P. C., 2d Lieut., 15th Bat. Headquarters Co., F. A. R. D.,	Camp Jackson, S. C.
CLAUSEN, E. H., Capt., General Engineer Depot, 1438 You St., N. W.,	Washington, D. C.
COHEN, JULIUS M.	Capt., 319th Engineers, Camp Fremont, Cal.
CRAIG, JOHN J.	2d Lieut., 311th Engineers, Camp Grant, Ill.
CRAMPTON, FRANK A.	Sgt., 115th Engineers, Camp Humphreys, Va.
CRONIN, PAUL B.	1453 Oak St., Glendale, Cal.
CROSTON, JOHN J., 1st Lieut., Co. A, 27th Engineers, A. E. F., Care Postmaster, N. Y.	
DAGGETT, ELLSWORTH.	349 West 58th St., New York, N. Y.
DAHL, SIMEON K.	Instructed to hold everything.
DAKE, C. L.	Missouri School of Mines, Rolla, Mo.
DANIEL, JOSEPH A.	Instructed to hold everything.

- DARRINGTON, PAUL N., 1st Lieut., 46th U. S. Infantry, Camp Sheridan,
Montgomery, Ala.
- DAVIS, ANGUS W.....Lieut.-Col., Care C. E. T. D., Seaford, England.
- DEANE, W. A.....Instructed to hold everything.
- DETWEILER, A. N.....American Zinc & Chemical Co., Langeloth, Pa.
- DEVEREUX, WILLIAM G.....Major, 144th Field Artillery, Camp Kearney, Cal.
- DOELLE, HENRY E., Cadet, Army Aeronautical School, Squadron 11,
Camp Dick, Dallas, Texas.
- DONDERO, F. NICHOLAS.....Co. F, 316th Engineers, Camp Merritt, N. J.
- DRAKE, M. C., 2d Lieut., Headquarters Co., 325th Infantry, A. E. F.,
Care Postmaster, N. Y.
- DUDLEY, HARRY C., Capt., Co. B, 36th Engineers, A. E. F., Care Postmaster, N. Y.
- DUGGLEBY, A. F....Sgt., Co. A, 27th Engineers, A. E. F., Care Postmaster, N. Y.
- DYRENFORTH, DONALD.....Gen'l Supt., Akron Mines, Whitepine, Colo.
- EBERHARDT, WILLIAM G.....450 West 22d St., New York, N. Y.
- EDMONDSON, H. W.....Capt., E. R. C., 28th Engineers, Occoquan, Va.
- EDWARDS-LECKIE, JOHN, Colonel, 2d Canadian Reserve Training Brigade,
Shornecliffe, England.
- EDWARDS-LECKIE, R. G., Major-General, Military District No. 11,
Victoria, B. C., Canada.
- EMMENS, NEWTON W., Geol., H. A. Fisher Co., 600 Magee Bldg., Pittsburgh, Pa.
- ENOS, HERBERT C., Mgr., International Min. & Smelt. Co. of Mexico,
Apartado 101, San Luis Potosi, Mexico.
- EPPLEY, MARION, Lieut. Comm. U. S. N. R. F., 16 Sheffield Ave., Newport, R. I.
- FAIR, FRED A., Pres. & Gen'l Mgr., Fred A. Fair Engineering Assoc., Boulder, Colo.
- FARISH, FREDERICK G.....318 Fourteenth St., Denver, Colo.
- FELL, HAROLD B., 1st Lieut., Field Artillery Replacement Depot, Camp Jackson, S. C.
- FINUCANE, T. R.....83 Hawthorn St., Rochester, N. Y.
- FISHER, NORMAN R.....Thetford Mines, Province of Quebec, Canada.
- FORBES, CARROLL R.....Capt., 113th Engineers, Camp Shelby, Miss.
- FORBES, D. D., Draftsman, Consolidated Arizona Smelt. Co., Humboldt, Ariz.
- FORBES, J. HYDE.....1638 Fourth Ave., Los Angeles, Cal.
- FOWLES, CHARLES.....San Lucas de Ocampo, Durango, Mexico.
- FRENCH, STUART W.....363 Grove St., Pasadena, Cal.
- FUNSTON, E. N.....Mountain Grove, Mo.
- GAHL, RUDOLF, Inspiration Cons. Copper Co., 42 Broadway, New York, N. Y.
- GARNETT, T. H.....The Empire Zinc Co., Gilman, Colo.
- GEHRES, GEORGE W.....Wheeling Steel & Iron Co., Wheeling, W. Va.
- GEORGE, P. W.....Baxter Springs, Kansas.
- GIBB, ALLAN.....Capt., Royal Engineers, F. E. xxii Corps, B. E. F.
- GIBBS, GEORGE H....."Belmont" Lichfield Road, Rushall, Walsall, England.
- GILL, JAMES P.....Box 1412, Great Falls, Mont.
- GLEASON, P. R.....4 Taylor Ave., So. Norwalk, Conn.
- GORDON, WILLIAM D., Pres., Camphuis Rives & Gordon, Inc.,
81 New St., New York, N. Y.
- GOW, PAUL A.....Mgr., Tuolumne Copper Min. Co., Butte, Mont.
- GREEN, WALDRON A.....Co. C, 27th Engineers, A. E. F., Care Postmaster, N. Y.
- GREIT, ADOLPH J.....Neptuna 273, Havana, Cuba.
- HAAS, HERBERT, Care Los Angeles Shipbuilding & Dry Dock Co., San Pedro, Cal.
- HALEY, DENNIS F., Asst. Mgr., The American Metal Co., Ltd.,
822 A. C. Foster Bldg., Denver, Colo.
- HALL, C. W.....Care Primos Exploration Co., Empire, Colo.
- HAMILTON, O. ROSS, Capt., Co. B, 28th Engineers, A. E. F., Care Postmaster, N. Y.
- HAMMILL, CHESTER A.....Box 333, Brownwood, Texas.
- HAMMON, W. C.....1st Lieut., 4th Engineers, A. E. F., Care Postmaster, N. Y.
- HART, PHILIP E.....Lieut., Royal Engineers, B. E. F., France.
- HAZARD, ARCHIE M.....Co. A, 604th Engineers, Camp Leach, Washington, D. C.
- HAZELTINE, ROY S., Chief Chem., The Greenwood Co.,
305-9 Finance Bldg., Kansas City, Mo.
- HEILMAN, JOSEPH C.....4th Co., 166th Depot Brigade, Camp Lewis, Wash.
- HESSE, HERMAN V., Mgr. Coal Operations, Monongahela Valley Traction Co.,
Watson Bldg., Fairmont, W. Va.
- HILBY, GEORGE R.....Lieut., A. S., S. R. C., Ellington Field, Texas.
- HINDSHAW, H. H., Cons. Min. Engr. & Geol., 947 Greenwood Ave., Ann Arbor, Mich.
- HOLLISTER, SCOVILLE E., Recruit Detachment, 311th Aero Squadron,
March Field, Riverside, Cal.
- HOLSTEIN, P. F.....Casilla 117, Care Du Pont Nitrate Co., Taltal, Chile.

- HOTCHKIN, HARRY 1st Lieut., 539th Engineers, N. A., Camp Gordon, Ga.
 HOUSEHOLDER, E. ROSS 226 No. Enterprise St., Bowling Green, Ohio.
 HSUEH, K. L. Benson Mines Co., Benson Mines, N. Y.
 HUANG, SAOSAN KEN Asst. Supt., Tayeh Iron & Steel Works, Tayeh, China.
 HULL, M. R. Nevada Cons. Copper Co., McGill, Nev.
 ICKES, E. L. 10 Victoria St., Westminster, London, S. W. 1, England.
 INCH, JOSEPH, Mgr., Sociedad de Las Minas de Cobre de San Bartolo,
 San Pedro de Atacama, Antofagasta, Chile.
 JARVIS, R. P. Care Cananea Cons. Copper Co., Cananea, Sonora, Mexico.
 JOHNSON, F. A. Care Standard Oil Co. of New York, Shanghai, China.
 JOHNSTON, JOHN M., Asst. Engr., N. W. M. & Ex. Co., Dagus Mines, Elk Co., Pa.
 KAMP, W. H., 2d Lieut., 57th Aero Squadron, A. E. F., Care Postmaster, N. Y.
 KEENE, EDGAR F. 1 London Wall Bldg., London, E. C., England.
 KELLEY, ARTHUR L., Ray-Kelvin Min. Co., 418 National Bank of Arizona Bldg.,
 Phoenix, Ariz.
 KING, FREDERICK G., Pres. and Gen'l Mgr., Boston-Pacific Oil Co.,
 1016 Mills Bldg., San Francisco, Cal.
 KIRKPATRICK, G. H., Lieut.-Col., 11th Canadian Mounted Rifles, C. E. F., France.
 KLEPETKO, ERNEST 609 Locust St., Anaconda, Mont.
 KLEPINGER, JOHN H. Box 1771, Great Falls, Mont.
 KOCH, H. E. Creve Coeur, Mo.
 KRAUS, EDGAR United Verde Extension Min. Co., Jerome, Ariz.
 KREJCI, MILO W. Care International Lead Refining Co., East Chicago, Ind.
 KUZELL, CHARLES R. United Verde Copper Co., Clarkdale, Ariz.
 LONDON, ROBERT R., 1st Lieut., Signal Officers' Reserve Corps, A. E. F.,
 Care Postmaster, N. Y.
 LONDON, STEPHEN L. U. S. Naval Base, Brest, France.
 LASKEY, BERNARD H., Master Engr., Headquarters Co., 316th Engineers,
 Camp Lewis, Wash.
 LATHAM, EVERETT B., Dept. of Justice, 1033 Merchants National Bank Bldg.,
 Los Angeles, Cal.
 LEWIS, ROBERT S. Huntington Lake, Cal.
 LINCH, HARRY A., 1st Lieut., Headquarters Co., 345th Field Artillery,
 N. A., A. E. F., Care Postmaster, N. Y.
 LINDSLEY, NORMAN D., 1st Lieut., Co. E, 318th Engineers, A. E. F.,
 Care Postmaster, N. Y.
 LOGAN, WILLIAM W. Care George Malcolm, 1009 54th St., Oakland, Cal.
 LOVE, JAMES W., Lieut., Battery E, 347th Field Artillery, A. E. F.,
 Care Postmaster, N. Y.
 LOW, JOHN C., Capt., U. S. R., 308th Engineers, A. E. F., Care Postmaster, N. Y.
 LYON, GEORGE J., Capt., Engr. R. C., Asst. to Constr. Q. M., Schenectady, N. Y.
 LYTZEN, W. W. Geol., Cons. Interstate-Callahan Min. Co., Wallace, Idaho.
 MCCUTCHEON, KENNETH C., 1st Lieut., 4th Co. Coast Artillery,
 Fort Winfield Scott, Cal.
 MCINTYRE, JOHN E. Ocean Park, Cal.
 MCKECHNIE, B. E. Franklin, N. J.
 MACISSAC, DONALD, Lieut., Co. B, 11th Engineers (Railway), A. E. F.,
 Care Postmaster, N. Y.
 MACMILLAN, HERBERT 1st Lieut., C. A. C., Ft. H. G. Wright, N. Y.
 MACVICHIE, DUNCAN 1109 Boston Bldg., Salt Lake City, Utah.
 MAHONEY, J. N. 574 81st Street, Brooklyn, N. Y.
 MANSFIELD, M. Sgt., Bat. E, 348th Field Artillery, Camp Lewis, Wash.
 MAXWELL, NORMAN E. Co. 4, E. R. O. T. C., Camp Lee, Va.
 MAY, ALBERT E. Texline, Texas.
 MELITZER, SAMUEL, 2d Lieut., Engineers, N. A., Quarters No. 14,
 Washington Barracks, Washington, D. C.
 METZ, GILBERT F., Ensign, U. S. N. R. F., U. S. Naval Academy, Annapolis, Md.
 MEWHIRTER, SYDNEY A., 1st Lieut., Co. D, 314th Engineers, 89th Div.,
 A. E. F., Care Postmaster, N. Y.
 MILLS, RONALD VAN A., Pet. Technologist, U. S. Bureau of Mines, Washington, D. C.
 MITCHELL, LEROY B., Lieut., 65th American Engineers, Tank Service, England.
 MOORE, PHILIP N. 805 Merchants-Laclede Bldg., St. Louis, Mo.
 MORGAN, GEORGE DODD, Co. B, Camouflage Section, 40th Engineers, A. E. F.,
 Care Postmaster, N. Y.
 NAGEL, H. P., JR. Min. Supt., Sunnyside Min. & Mill. Co., Eureka, Colo.
 NESBIT, MILLARD F. 4th E. R. O. T. C., Camp Lee, Petersburg, Va.
 NOBLE, CLARKE O., 2d Lieut., Headquarters, 638 Aero Squadron, U. S. Air Service,
 35 Eaton Pl., London, S. W. 1, England.

- NORCROSS, FRED STEPHENSON, JR. Capt., 27th Engineers, Camp Meade, Md.
 NORDENHOLT, GEORGE D. 1202 Hollingsworth Bldg., Los Angeles, Cal.
 NOTT, T. E., School of Military Aeronautics, Cornell University, Ithaca, N. Y.
 NOWLAN, H. H., 1st Lieut., 20th Field Artillery, A. E. F., Care Postmaster, N. Y.
 PAGE, E. R., 1st Lieut., Aviation Section, Signal Corps, A. E. F.,
 Care Postmaster, N. Y.
 PALMER, W. R. 701 Mesa Ave., El Paso, Texas.
 PAPE, PAUL F. Care Chino Copper Co., Hurley, N. M.
 PATTERSON, S. B., Jr., 1st Lieut., Engr. R. C., Co. 1, E. O. T. C.,
 Camp Lee, Petersburg, Va.
 PAYMAL, GEORGE W. Supt., Yellow Aster Min. & Mill. Co., Randsburg, Cal.
 PEARSON, ALFRED, JR. Capt., Engrs. R. C., U. S. A., Camp Lee, Va.
 PEMBERTON, J. R. Geol., Pemberton & Severy, 216 Unity Bldg., Tulsa, Okla.
 PERRY, JOHN E. Pres., Valley Mould & Iron Corp., Sharpville, Pa.
 PERRY, OSCAR B., Lieut.-Col., Headquarters, 27th Engineers, N. A.,
 Camp Meade, Md.
 PETERSON, CLARENCE J., Care W. L. Walker, 504 Ft. Worth National Bank Bldg.,
 Ft. Worth, Texas.
 PETZEL, CHARLES L., Corp., Co. B, 302d Field Signal Battalion, A. E. F.,
 Care Postmaster, N. Y.
 PITMAN, S. M. Isle of Springs, Mo.
 PLACE, RICHARD G. Chief Chem., Vermont Copper Co., So. Strafford, Vt.
 PLUMHOF, W. J. 425 Logan Ave., Salt Lake City, Utah.
 POWELL, D. A., Candidate, 1st Training Co., 5th Training Camp, C. A. C.,
 Fort Monroe, Va.
 PRATT, JOSEPH HYDE, Lieut.-Col., 105th Engineers, 30th Division, A. E. F.,
 Care Postmaster, N. Y.
 PRICE, WILLIAM R. Montana Club, Helena, Mont.
 REED, MAURICE J., 2d Lieut., S. R. C., A. S., Unattached, Annex Forces, A. E. F.,
 Care Postmaster, N. Y.
 REESE, JOHN N., Asst. to 2d Vice-pres., Republic Iron & Steel Co.,
 Youngstown, Ohio.
 RIDDLE, DONALD D., Geol., Central Oil Syndicate of Denver, Box 61, Cisco, Tex.
 RISTEDT, E. J., 1st Lieut., Engrs. U. S. R., Care United Service Club,
 Dupont Circle, Washington, D. C.
 ROBBINS, H. R., Capt., N. A., General Staff, 727 Quebec St., N. W., Washington, D. C.
 ROBERTS, DUDLEY E., Sgt., Engr. of Tests, Symington Machine Corp.,
 Rochester, N. Y.
 ROCKEFELLER, G. E. Enumelaw, Wash.
 ROCKWELL, F. G. Capt., 305th Engineers, A. E. F., Care Postmaster, N. Y.
 RODGERS, SELDEN S., Supt., Grinding & Flotation, Anaconda Copper Min. Co.,
 Anaconda, Mont.
 RUNYON, WALTER C. Scarsdale, N. Y.
 RYPINSKI, J. E. U. S. M. R. C., Overseas Depot, Quantico, Va.
 SAEGER, C. MARSHALL, JR., Junior Chem., Chem. Met. Dept.,
 Bureau of Standards, 4109 Connecticut Ave., Washington, D. C.
 SANGER, ALAN B., Testing Dept., Anaconda Copper Min. Co., Anaconda, Mont.
 SCAIFE, HAZEL L., Capt., Care Aircraft Production, Castor Bean Growing Section,
 Washington, D. C.
 SCHABER, C. F. Lieut., U. S. R., 37th Infantry, Ft. McIntosh, Tex.
 SCHEURER, L. R. Rolla, Mo.
 SCHMIDT, H. E. Capt., Engrs. R. C., Camp Lee, Petersburg, Va.
 SCHUYLER, ARENT H. International Nickel Co., Port Colborne, Ont., Canada.
 SCOTT, JOHN T. 1st Lieut., 335th Infantry, Camp Sherman, Ohio.
 SEARLS, FRED, JR. 1st Lieut., Engineers, A. E. F., A. P. O., 714, France.
 SEGALL, JULIUS, Geol., The Greenwood Co., 305/309 Finance Bldg., Kansas City, Mo.
 SHAW, JOSEPH S., Inspector of Construction, U. S. Ordnance Dept., Gorgas, Ala.
 SHURICK, ADAM T., Capt., E. R. C., Co. A, 1st Replacement Engineers,
 Fort Foote, Md.
 SIMON, TREVOR B. 18 Condict Place, Morristown, N. J.
 SMITH, JAMES H., JR., Capt., Engr. R. C., Co. B, 304th Engineers, Camp Meade, Md.
 SMITH, LYON. 720 Race St., Denver, Colo.
 SMYTH, JOHN G., Capt., Officers' Reserve Corps, Production Div., Ordnance Dept.,
 2618 Dalton Ave., Los Angeles, Cal.
 SOPER, RALPH H. 19th Floor, 65 Broadway, New York, N. Y.
 SPEED, F. B., JR. Catonsville, Md.
 SPOOR, HARRY M. Instructed to hold everything.

STACK, FRANK L.	Ordinance Supply School, Camp Hancock, Ga.
STADER, J. A.	Capt., Field Artillery, O. R. C., P. O. No. 718, A. E. F.
STAHL, H. R.	Desloge, Mo.
STEMMER, J. H.	Driggs, Ida.
STEPHENSON, F. L.	U. S. Naval Aviation Detachment, Mass. Institute of Technology, Cambridge, Mass.
STEVENS, GEORGE R.	608 Carter Bldg., Houston, Tex.
STEWART, LEIGHTON	Lieut., Canadian Engineers, C. E. F., France.
STEWART, M. B.	Battery, 4th O. T. C., Camp Shelby, Miss.
STOCKETT, N. A.	2d Lieut., N. A., Co. D, 306th Engineers, Camp Sevier, S. C.
STOUT, HERBERT A.	Min. Engr., United States Gypsum Co., Fort Dodge, Iowa.
STOWELL, G. E.	Oregon Bureau of Mines & Geol., 417 Oregon Bldg., Portland, Ore.
SULLY, KENNETH M.	Sgt., Co. F, 604th Engineers, Washington Barracks, D. C.
SUMAN, JOHN R.	Box 82, Mineral Wells, Tex.
SUMMERHAYES, MAURICE W.	Mgr., Bluestone Min. & Smelt. Co., Mason, Nev.
SWEET, A. T.	Lieut., 107th U. S. Engineers, Headquarters Co., A. E. F., Care Postmaster, N. Y.
TERRY, MARK L.	Lieut., Headquarters Co., 346th Field Artillery, N. A., 89th Div., A. E. F., Care Postmaster, N. Y.
THORNHILL, E. BRYANT	Room 2817, 120 Broadway, New York, N. Y.
TINSLEY, ROBERT B.	Capt., Co. A, 605th Engineers, Camp Forrest, Ga.
TOENGES, ALBERT L.	435 E. Mt. Airy Ave., Mt. Airy, Philadelphia, Pa.
TOLMAN, JOHN D.	Champion Copper Co., Painesdale, Mich.
VAN CAMPEN, F. R.	Supt., Bering River Coal Co., Cordova, Alaska.
VISEL, C. E.	49 Morse St., New Haven, Conn.
VRANG, C.	A. S., S. E. R. C., Stanford University, Cal.
WAITE, VICTOR R.	Room 225, Hurt Bldg., Atlanta, Ga.
WALSH, J. K.	Lieut., Headquarters Co., 89th Div., 340th Field Artillery, A. E. F., Care Postmaster, N. Y.
WANVIG, JOHN D., JR.	Box 1367, Phoenix, Ariz.
WARD, HARRY J.	1st Lieut., A. S., Sig. R. C., Care Curtiss Aeroplane & Motor Corp., Buffalo, N. Y.
WEARNE, WILLIAM	Supt., Inland Steel Co., 2422 East 3d St., Duluth, Minn.
WEBB, TORREY H.	1st Lieut., Signal Corps, Aviation Section, U. S. Army.
WECK, CHARLES A.	501 Third Ave., San Francisco, Cal.
WEIMER, RAYMOND S.	Co. 6, E. O. T. C., Camp Lee, Va.
WEINBERG, G. S.	Box 170, Morris Plains, N. J.
WHELOCK, CHARLES F.	Mgr., Stout's Mountain Coal Co., Hanceville, Ala.
WHITFIELD, H. E.	Care Agent General for Western Australia, Savoy House, Strand, London, W. C., England.
WILLIAMS, RALPH O.	Lieut., Co. F, 319th Infantry, A. E. F., Care Postmaster, N. Y.
WRAITH, CHARLES	Capt., O. R. C., Edgewood Arsenal, Stamford, Conn.
WRIGHT, H. B.	Care Pocahontas Fuel Co., Pocahontas, Va.
WRIGHT, H. F.	1st Lieut., Co. B, Second Regiment, Oklahoma National Guards.
YOUNG, FRED W.	2d Lieut., Aviation Section, Signal Corps, A. E. F., Care Postmaster, N. Y.
ZIMMERSCHIED, K. W.	Care General Motors Corp., 1764 Broadway, New York, N. Y.

CHANGE OF ADDRESS OF MEMBERS

The following changes of address of members have been received at the Secretary's office during the period June 10, 1918 to July 10, 1918.

This list together with the list published in Bulletin Nos. 133 to 139, January to July, 1918, and the foregoing list of new members, therefore, supplements the annual list of members corrected to Jan. 1, 1918 and brings it up to the date of July 10, 1918.

ADAMS, LELAND D.	Care Weedon Min. Co., Eastern Townships Bank Bldg., Montreal, Canada.
ALBI, CHARLES	1650 Vin St., Denver, Colo.
ALSDORF, F. C.	150 West 47th St., New York, N. Y.
ANDERSON, BARCLAY G.	Co. B, 318th Engineers, A. E. F., Care Postmaster, N. Y.
ANDERSON, GEORGE K. JR.	Lieut., 30th Co., 3d Replacement Regiment, Camp Gordon, Ga.
ANDERSON, RAY B.	11 Cliff St., New York, N. Y.

CONOVER, M. J.	Hotel Bellevue, San Francisco, Cal.
DENNIS, PAUL J.	Bisbee, Ariz.
DETERT, WILLIAM F.	Jackson, Amador Co., Cal.
EHLEBS, LOUIS W.	2137 St. Louis Ave., St. Louis, Mo.
FAIRBAIRN, ALAN J.	St. John Mining Co., Monteruma, Colo.
FIELDING, SIR CHARLES	Belmont, Faversham, Kent, England.
HESS, K. F.	Ray Consolidated Copper Co., Ray, Ariz.
HOVLAND, HENRY B.	Los Angeles Athletic Club, Los Angeles, Cal.
KAY, DAVID NELSON	Ray Consolidated Copper Co., Hayden, Ariz.
KERNAN, THOMAS H.	School of Mines Experiment Station, Univ. of Minnesota, Minneapolis, Minn.
KLUGESCHIED, WALTER P.	616 West 113th St., New York, N. Y.
KONSELMAN, ALBERT S.	Globe, Ariz.
LEVY, MILTON M.	525 Cache La Poudre St., Colorado Springs, Colo.
MATLACK, E. V.	Terminal Hotel, St. Louis, Mo.
PRIOR, CHARLES E.	Mexico.
REICHEL, DAN H.	Piedra Magnesite Co., Piedra, Cal., via Reedley, Cal.
ROBERTS, EDWARD J.	Nevada Pyramid Min. Co., Riverside Hotel, Reno, Nev.
ROGERS, BENJAMIN CARROLL	Box 233, Millin, Tex.
ROSS, HERBERT W.	314 Pacific Ave., Piedmont, Oakland, Cal.
SIMPSON, KENNETH M.	57 Post St., San Francisco, Cal.
STICKNEY, WILLIAM H.	708 N. Center St., Reno, Nev.
Woo, W. K.	N 70 Sing Kong Li, Minghong Road, Shanghai, China.
YOUNG, LEWIS E.	619 W. Springfield Ave., Champaign, Ill.

NECROLOGY

The deaths of the following members were reported to the Secretary's office during the month of June 10, 1918, to July 10, 1918.

Date of Election.	Name.	Date of Death.
1916	Bailey, L. N.	April 30, 1918.
1904	Collins, E. A.	June 3, 1918.
1889	James Douglas	June 25, 1918.
1886	Larsson, Per	May 5, 1918.
1887	Phillips, William B.	June 1918.
1886	Reece, Fred B.	
1916	Roper, George, Jr.	May 25, 1918.

BIOGRAPHICAL NOTICES

JAMES DOUGLAS

Dr. James Douglas, twice President of the American Institute of Mining Engineers, and one of its principal benefactors, died in New York on June 25, 1918, at the age of 81 years. After a life of extraordinary activity, failure of his health compelled him to retire about 2 or 3 years ago, and in view of his advanced years his death was not unexpected. His funeral was held at the Church of the Mediator, on June 26, and was attended by representatives of the American Institute of Mining Engineers and of the Canadian Mining Institute. His body was then taken to Quebec for burial in the family plot.

An extended notice of Dr. Douglas, prepared by Dr. R. W. Raymond, will be presented in the September issue of the Bulletin.

LEWIS NEWTON BAILEY

Lewis Newton Bailey died of pneumonia at Camp Merritt, N. J., April 30, 1918, at the age of 34 years. He was Master Engineer, Senior Grade, in the Fourth Regiment, U. S. Engineers, and although he was offered a commission as First Lieutenant shortly after enlisting, he preferred not to accept it until he had reached France. By those who knew him well, this lack of eagerness for promotion will be recognized as consistent with his whole character.

Mr. Bailey was born at San Diego, Cal., May 28, 1884, and graduated from the University of California, College of Mines, in 1906. He joined the American Institute of Mining Engineers in 1916. During 1904 he was employed at the cyanide plant of the Buckeye mines, Forest Hills, Cal. In the autumn of 1909 he went to the Coeur d'Alene District, Idaho, and was first employed on construction work of the Bunker Hill & Sullivan Mining & Concentrating Co., with a short intermission at the Hercules mill, after which he was sampler and assayer for the Bunker Hill & Sullivan Co. until May, 1910, when he was obliged to return to California to attend to family interests.

Returning to the Coeur d'Alene district in November, 1911, he was given charge of remodelling and operating the mill of the Coeur d'Alene Development Co., treating the output of the Ontario mine; this work he performed with credit and complete success. In December, 1914, he returned to the Bunker Hill & Sullivan Co. as assistant metallurgist and mill superintendent, his work consisting mainly in the testing and improvement of concentrator practice, which he continued with great credit until August, 1915, when family considerations required that he again return to the home of his parents at San Diego.

Mr. Bailey was characterized by energy, both physical and mental, by devotion to his friends, associates and employer. He was particularly successful in his relations with the men under him and, in fact, was thoroughly well liked by everybody with whom he came in contact. He took a great interest in technical matters and his inclination was strongly toward research investigations. At the same time he was effective in manual and mechanical work and was generally found working side by side with the men under his direction. His nature was unselfish and he was extremely popular socially. He was a member of the Coeur d'Alene Commandery, Knights Templar. STANLY A. EASTON.

EDWARD DYER PETERS

Shortly after the death of Prof. Edward Dyer Peters, on February 17, 1917, the Institute prepared for publication a brief outline of Prof. Peters' life, recording simply the most prominent features of his distinguished career. At the request of Prof. Peters' sister, Mrs. Edward McClure Peters, the publication of this notice was postponed in order to give her an opportunity to publish a more lengthy, detailed, and intimate account of her brother's life. This has now been published (The Knickerbocker Press, New York, 1918) and through the kindness of the author, thirty copies have been put at the disposal of the Institute, for distribution among those members, in order of application, who were most interested in Prof. Peters. The following paragraphs are extracted from this work, although space forbids the reproduction of a large amount of most interesting details, most of which are contained in letters from Prof. Peters to members of his family, written from different parts of the world, wherever Prof. Peters happened to be engaged in professional work.

Edward Dyer Peters, the only child of Henry Hunter Peters and Susan Barker Thaxter, was born in Dorchester, Mass., June 1, 1849. From his father he was a descendant of the Peters family of Ipswich and Andover, Mass., whose earliest ancestor settled in Essex County in 1659; while upon his mother's side he descended from several old Hingham families, as well as from the Quincys and from Governor Bradford.

Between the ages of fourteen and sixteen he was a student at the

Episcopal School for boys in Cheshire, Conn. Near the school was an old tin mine, and he used to spend his Saturday afternoons exploring it.

When Edward was sixteen, his father sold his property in Southborough, and for the next three years lived in Europe. Sept. 26, 1865, Edward entered the Royal School of Mines at Freiberg, Saxony.

In the summer of 1867 he joined his family on Lake Geneva, and spent a part of the season in that vicinity, going to Chamounix and taking other trips. Extract from a letter to his father:

Elbingerode, Harz, Aug. 30, 1868: I left Freiberg with my friend Lillienthal, on Wednesday, the 19th of August, reached Leipzig in the evening and spent the night in that city: the next morning we took the cars and in the afternoon reached Eisleben, in Prussia, which was to be our first stopping-place; there are immense copper-mines and smelting-works at this place, and the method of working the mines is very peculiar

The next morning we got up at five and spent the whole day in the smelting-works where I obtained a number of drawings of the furnaces they use here and a good many valuable data. Saturday morning we got up at four o'clock, and descended a mine about three miles from the town; the Director of this mine was one of the most intelligent and agreeable men that I ever met; he accompanied us in the mine and explained everything that was new to us. The system of mining at Eisleben is peculiar to this town, and is not used at any other place in the world; the copper ore comes in narrow, flat veins eighteen inches high, at the utmost, consequently the men work lying flat on their left side and using the pick with both hands: the ore is carried out of the side passages into the main ones, in very low waggons about twelve inches high, and four by two feet; the boys who pull these waggons have a board buckled to their left thigh and their left arm; they pass their bare foot through a strap in the waggon and wriggle along on their side dragging the waggon after them, with their foot, almost as fast as a man can walk above ground. In the afternoon we walked over to Hittstadt, about twelve miles, and remained there Sunday and Monday. Monday night, at ten o'clock we went out to one of the smelting-works, to see the refining of the copper; this is only done at night, so we worked there from ten in the evening till eleven the next morning, and came home all blackened up and with blistered hands, for our skin was not quite so tough as that of the workmen: at noon the same day, we took the stage to Ascherleben, and then the train to Stassfurt, where there are immense salt-mines, as well as factories for the manufacture of bromium, which latter process is, however, kept a profound secret, so we had very little hope of seeing anything but the salt mines; we were talking with our landlord about our disappointment, that evening, when he told us that the director of the Bromium works was sitting in the next room with no company but his glass of beer, so we went over to him, introduced ourselves as Americans, and actually succeeded in persuading him that it could do his business no earthly hurt if he showed us his works; at last he consented, after making us give our word of honor not to divulge any of his secrets on this side of the water, and I now have, in my notebook, very accurate notes on the whole process. The next day we accomplished a good deal; we descended two mines, visited the Bromium works, and succeeded in catching the last train for Ballinstadt, in Anhalt-Bernberg. Friday morning we walked over to 'Victor's Hütte,' twelve miles, where there are very bad smelting-works, but a magnificent dressing of the ores for smelting; as this will certainly be a very important subject in the Territories, where fuel is so scarce, we devoted that afternoon and the whole of the next day to it; I filled twenty-one pages of my notebook with sketches and measurements of the different machines in use at these works; they are all remarkably simple and cheap, but extremely practical; yesterday (Saturday) I made the longest walk that I have ever made in my life; we left 'Victor's Hütte' at seven A.M. and reached this place at ten P.M., passing through the most beautiful portions of the Harz; our walk, in a straight line, measures on the large map, thirty-one English miles, but counting in all the turnings and twistings of the paths that we took, must have been at least forty. We each carried a heavy knapsack, or rather satchel, and a shawl, and when we reached this place were pretty well knocked up, so I am not at all sorry that we are to rest to-day. So far our trip has been eminently successful, and I have learned a great deal and obtained a great many valuable drawings, etc., in a very short time."

During the latter part of his residence at Freiberg he was president of the Anglo-American club, then composed of about forty-two students, and in this capacity, he was the host at a dinner given by the club to the Crown Prince of Saxony.

In the summer of 1869 he returned home, and in the fall of the same year he left for Colorado. For two or three years he was at Denver, Central City, Fairplay, Breckenridge, and Dudley.

Extract from a Colorado paper 1870 or 1871:

MIDDLE BOULDER: SILVER BULLION SHIPMENTS. The first two shipments of silver from A. D. Breed's new reduction works at Middle Boulder were made within the past five days. The first of these embraced four hundred pounds, and the last 6,200 ounces of silver, in bars, the product of ore from the Caribou mine. The bullion has been forwarded to New York Under the skillful management of such competent millmen as Charles E. Sherman and E. D. Peters, this mill will henceforth be found all that could be desired and will take the lead in Colorado in the production of silver bullion.

From another Colorado paper of a little later date (1872):

A Good Appointment: Edward D. Peters, a young man of rare abilities and acquirements, and who has few equals, theoretically or practically, in mining and milling, has been appointed and confirmed Territorial Assayer for the Southern District of Colorado, the office being located at Fairplay, Park County. At present Mr. Peters is engaged at A. D. Breed's Reduction Works, at Middle Boulder, as assayer. We congratulate him upon his appointment, and the people of the South in obtaining the services of so thorough and correct a metallurgist.

His first contributions to the *Engineering and Mining Journal* were made at this time, while he was assayer at the first Caribou Silver Mill, in Boulder County, when he sent some brief notices, on milling results, to Dr. Raymond.

From July, 1871, to March, 1872, he was superintendent and metallurgist of the largest silver mine in the country (the Caribou)—which position he resigned, having received an appointment in February, 1872, from the Governor of the Territory, as territorial assayer for the southern part of Colorado. In the fall of the same year he built the Mt. Lincoln smelting works; he writes from Dudley, February 1st, 1873.

It is a beautiful winter's morning and I can hardly realize that I am in the centre of the Rocky Mountains almost eleven thousand feet above you. My office is in a little flat, surrounded by thick pine forests, and just at the very foot of the highest peak in this whole range from British America to Mexico. The ground commences rising from my very doorstep, and in the course of one eighth of a mile, becomes so steep, that only the little Mexican jacks can be used to pack up provisions and supplies to our mines, which are situated almost on the summit of the highest peaks. As the snow lies some five feet in the timber on the mountain sides, even they are useless now, and are down on a rancho in the valley, some fifty miles from here, dying as fast as they can, from the epizootic. We have lost some forty in the last month, and all the horses have it so badly that we only get our mails from Denver every two or three weeks, brought up by bull-teams. The smelting-furnace, which I built last fall, and for which I imagine that I have the same sort of affection that a mother has for a pet child, is running finely, without any delays or drawbacks, and is building me up quite a reputation throughout the territory. When I came here I was simply 'Professor' or 'Captain' (every man has a title out here you know). When the furnace started up successfully I was at once dubbed 'Major' and since then have usually been addressed as 'Colonel.' I expect a Brevet Generalship shortly, as promotion is rapid in this country, but if I should ever make a failure it would not take long to degrade me to the ranks. However, I am not afraid of that. The ores are easily treated. There is a fascination in the business that I am engaged in that you will not appreciate. It is certainly a pleasant trade to take the muddy ore from the mines, to determine its exact value and pay for it, to put it through the different furnaces, and finally bring out the gold, silver, copper, and lead, and above all to have the products agree exactly with the amount that you promised beforehand. There is a touch of the old alchemist's mysteries about it which renders it always new and interesting, and one feels every day that he is not only adding to the material wealth of the world, but is also filling his own mind and pocket.

In November, 1874, he returned to the East. Mining was at that time in a very low state; the ores in Colorado were supposed to be worked out, and Peters gave up all hope of continuing in his chosen profession

and entered Harvard Medical School, graduating thence in 1877, and being first in a class of one hundred and sixty; this gave him the degree of Doctor of Medicine, by which he was thereafter always known. He was the only medical graduate whose thesis was mentioned on the Commencement program of that year. He practiced medicine in Dorchester from 1877 until 1880, then returned to his original profession.

On Sept. 28, 1881, he married, in Dorchester, his cousin, Anna Quincy Cushing, the daughter of his mother's sister and of Dr. Benjamin Cushing.

For some years after this date Dr. Peters was associated with and originated some of the largest American copper and nickel smelting establishments.

In the summer of 1881 he was employed by the Orford Nickel and Copper Company.

In the summer of 1882 he was at the Ely mine, Vermont, as manager, and in November of the same year he returned to the Orford Nickel and Copper Company, being the first metallurgical manager of their works at Bergen Point, New Jersey.

In 1882 and 1883 he made contributions on the metallurgy of copper to *The Mineral Resources of the United States*, and a little later contributed a series of papers to the *Engineering and Mining Journal* which in 1887 were published in book form under the title of *American Methods of Copper Smelting*, his first and probably his most valuable and important work.

In the fall of 1883 he was in Ansonia, Conn., with Mr. Franklin Farrell, of that town, and in the spring of 1884 he accompanied Mr. Farrell to Butte, Montana, where he erected the first successful concentrating and smelting works of the Parrott Silver and Copper Company.

In November of this year, 1884, he returned home, finding himself unable to face a winter in so cold a climate; he remained in Dorchester during the greater part of 1885, being engaged in some work in East Boston, as well as in making drawings for the refining plant of the Calumet and Hecla; these plans were, however, not used.

Early in the year of 1886, Dr. Peters, having for some time felt the need of country life, and desiring some occupation beside his profession, purchased a farm at Walpole, about fifteen miles out of Boston, where he began to raise ducks with distinct success, but which he was obliged to give up, within two or three years, on account of his many absences from home and of his wife's health.

From June, 1888, until the spring of 1890, he was connected with the Canadian Copper Company, at Sudbury, Ontario, as general manager, starting the first blast furnace in December, 1888, and the second one in September, 1889, for the production of nickel copper matte.

During the following year or two he was engaged, principally, in writing, and in 1891 he published an extended, revised, and corrected edition of his first literary work, under the new title of *Modern American Methods of Copper Smelting*.

Late in the year 1892 he received a cable requesting his presence in Tasmania, to report upon the Mt. Lyell mine, and to do some preliminary work there; this mine, of iron and copper, which with the exception of the Rio Tinto mines in Spain, was the largest mine of its kind in the world, was situated in a most inaccessible locality, and required a long and fatiguing journey to reach. It was in great part owned by the members of the Great Broken Hill Mining Company, of Australia.

Dr. Peters sailed from San Francisco in December, 1892, stopping at Honolulu, Samoa, and Auckland, and encountering a severe storm between the latter place and Sydney; this was one of the worst gales experienced in that locality in nearly twenty years, and injured a number of persons on the steamer; as the ship's surgeon had left at Auckland, Dr. Peters' medical knowledge was of great use to him, and of considerable advantage to the many passengers who had received injuries. While in Melbourne he was treated with great consideration, being made an honorary member of all the clubs of consequence, and leading quite a gay life socially.

In January, 1893, he started for Tasmania, landing at Launceston, going thence by train to Hobart, then by a small steamer to the western coast, taking a waggon from their landing place, Strahan, and finally riding the last thirty miles of the journey to the Mt. Lyell mine.

"*Mt. Lyell, Tasmania, Jan. 18, 1893.* I am thirty miles from even an attempt at civilization; there is only a trail in here suitable—or rather unsuitable—for pack-animals; the mail comes in once a week, brought by a native on a mule, and though a telegraph-line runs through the bush, within a few miles of us, yet it does us no more good than if it were a clothes-line. This is just the uncivilized, uncomfortable, backwoods kind of place that I have 'sworn off' from going to, but what won't we do for money? At any rate it is safe, there being neither wild beasts nor wild men in Tasmania.

"*Jan. 11. a. m.* To-day we start to walk over the proposed line of railway that I may decide on its suitability. A long, hard, twenty mile walk, with no trail; only the bush chopped out a little. The mail arrived unexpectedly last night: I find all the local and even the Sydney and Melbourne papers, are devoting from half to two columns to my arrival, biography, etc., which latter they must get from old American journals, as I have positively refused to speak either of myself or of my mission here, and have confined myself to speaking to the reporters, solely, about copper mines in the United States.

"I may have to spend some months here, for their main object, after once telling them that it will pay, is to have me put up a small plant, and smelt, and worse still, refine, a thousand or two tons of the ore, so that they can show the people in England, to whom they intend applying for capital, to build extensive works, that the process and method of treatment are already an established success.

"*May 22, 1893.* . . . I am all through at Mt. Lyell at last, and really feel badly to leave it and Schlapp the superintendent, and my Zeehan and Argenton friends, Beardsley, and Elburn and all; and my engineer-in-chief Cullen, and his three or four assistants, perhaps never to see any of them again—though the Company wants me to come out again and build and start the works, etc. Fortunately a winze which I started on a promising streak of ore, when I first came to the mine, has shown up such wonderful ore that two miners took out thirty thousand dollars in silver last week.

After some stay in London, Dr. Peters went to Paris for the winter of 1893 to 1894: he worked at the École des Mines preparing for a new edition of his work on copper smelting. On behalf of the Mt. Lyell company he visited the Rio Tinto mines in Spain in September, 1893, and later, the Mansfeld mines in Germany; as well as Freiberg in the spring of the following year.

Dr. Peters spent much of the summer of 1894 in the Western United States on behalf of the Mt. Lyell company, as well as in getting data for the rewriting of the seventh and very much enlarged edition of his book, which was issued in 1895 under the title of *Modern Copper Smelting*.

For some years thereafter, Dr. Peters was engaged in various mining enterprises, the most important of which was the opening of Las Esperanzas coal mines in Mexico.

Subsequent to his work in Mexico, Dr. Peters was in Missouri,—at the Cornwall copper mines, Ste. Genevieve,—and in Georgia. In

1901 he made a short business trip to Europe, and that winter he delivered a course of lectures at the School of Mines, Columbia University. In the spring of 1904, he was invited by President Eliot, of Harvard, to give a course of lectures on the metallurgy of copper, and in the fall of that year he was appointed Professor of Metallurgy at Harvard University. The summer of 1905 he passed in Europe, upon a pleasure trip, and in 1907 he published his second great work, *Principles of Copper Smelting*. In 1909 he was appointed Gordon McKay Professor of Metallurgy. In February, 1910, he was one of a commission to make the annual assay of the coin of the United States, at the Mint, at Philadelphia. In 1911 he published *The Practice of Copper Smelting*, which he wrote "to replace his former book entitled *Modern Copper Smelting*," although the demand for the latter kept up to such an extent that the publishers continued to print it.

In 1914 he bought a farm in Shirley, Massachusetts, and there spent the remaining summers of his life; he engaged in the raising of poultry and took great pleasure in this occupation and in motoring through the surrounding country.

In March, 1914, he delivered an address, before the Canadian Mining Institute, at Montreal, upon "The Production of Heat in Metallurgical Furnaces."

During the last year of his life he was not in his usual health; he died, very suddenly and peacefully, at his own home, upon the morning of the seventeenth of February, 1917, having been able to attend to his ordinary work up to the very last day of his life.

He was a member of the Harvard, the St. Botolph, and the Papyrus Clubs of Boston, of the Engineers Club of New York, and one of the earliest members of the American Institute of Mining Engineers (1872), of which he was at one time vice-president; he also belonged to the American Academy of Arts and Sciences, the American Association for the Advancement of Science, of which he also became a fellow in 1916, and to the American Geographical Society. He had received the degree of Doctor of Medicine from Harvard in 1877, and that of Dr. Ing. (Hon.) from the Royal School of Mines, Freiberg, Saxony, in 1914. For the last two years of his life his professorship was in the Massachusetts Institute of Technology as well as at Harvard, owing to the merging of the mining departments of these two bodies.

Beside the man of science and the professor, there was, also, something of the musician in Dr. Peters' nature. In 1877, or perhaps earlier, he began the study of the 'cello, which, though interrupted by long and repeated absences, was always resumed with satisfaction, and was through many years a relaxation and a solace.

The straightforward, practical views of life expressed by Dr. Peters became crystallized in the minds of his family, in such phrases as "Face the issue"; and "There is no reason why you should have a thing because you want it": he had himself thoroughly in hand, though his heart was there for all those who needed it. A near and dear member of his family writes: "I think he was essentially lovable, rigidly honest, and *square* in all business dealings, and always ready to 'face the issue,' a favorite expression of his."

He was absorbingly interested in the present war, and, in spite of his German education, his feelings were, from the first, pro-Ally: America's share in this world conflict would have been inexpressibly satisfying to him.

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Geology of the Oil Fields of North Central Texas

Discussion of the paper of DORSEY HAGER, to be presented at the Colorado meeting, September, 1918, and printed in *Bulletin* No. 138, June, 1918, pp. 1109 to 1118.

WALLACE E. PRATT, Wichita Falls, Tex. (written discussion*).—Mr. Hager has touched upon interesting problems related to the broad subject with which he has entitled his paper.

As to the existence of the important structural feature in the buried Bend series, which Mr. Hager constructs from well-logs, and designates as the "Bend Arch," there seems to be general agreement among a number of observers. Indeed, M. G. Cheney¹ and Robt. T. Hill² have each published structural maps of the Bend Arch that do not differ essentially from the map shown in Mr. Hager's Fig. 1.

The reflection, in the overlying, unconformable Cretaceous, of certain folds in the Pennsylvanian, with which the petroleum accumulation has to do, is an important observation on the part of Mr. Hager, since, as he says, much critical territory is covered by Cretaceous, and it is highly desirable that the underlying Pennsylvanian structure be mapped, if possible.

If the folds in the Pennsylvanian are of post-Cretaceous age, then it should be possible, in spite of the intervening unconformity, to determine approximately the position of buried folds beneath the Cretaceous overlap. The idea of post-Cretaceous folding would not be out of accord with the suggestion by Carroll H. Wegemann that the folding of the Permian beds in southern Oklahoma was still in progress as late as the Tertiary.³ But most observers have related the folds in the Pennsylvanian and Permian beds at the surface, both in North Texas and southern Oklahoma, to the process of emergence of the land area at the end of the Permian.

It seems more probable that the reflection of Pennsylvanian folds in the unconformable Cretaceous which Mr. Hager observed is due to long continued persistence of stresses which were largely relieved at the close of the Permian, than that the principal period of folding was post-Cretaceous; this being the case, it seems likely that only folds of greatest intensity in the Pennsylvanian will be decipherable in the Cretaceous overburden, and that many promising structural features are so concealed by the Cretaceous as to escape detection except by drilling.

Mr. Hager concludes that the direction of the axes of most of the

* Received June 17, 1918.

¹ *Oil Trade Journal* (May, 1918), 9, No. 5, 75.

² *Ibid.* (June, 1918), 9, No. 6, 89.

³ U. S. Geological Survey, *Bulletin* 602 (1915), 34.

folds of the North Central Texas region is northeast-southwest, a smaller number having a northwest-southeast alignment. He touches here upon a subject intimately related to former shore-lines, old land areas, etc., which may well be made the theme of other specific contributions to the geology of North Central Texas. Exception may be taken to the general statement as to the relative number of folds on each of the two axial lines, it being admitted, however, that folds do occur along both sets of axes. It is my observation that a large majority of the folds in this area trend northwest, or west-northwest; in this category, also, may be placed most of the important folds, both from the viewpoint of size and of past production. These are the "dip-folds" of Hager, and their alignment follows the Wichita-Arbuckle trend so clearly displayed in the producing folds of southern Oklahoma, adjacent to North Texas.

It may be remarked, however, that many of the folds, the axes of which do trend northeast-southwest, are found in that part of the general area of which Mr. Hager writes, where he seems to have made most of his observations, namely, the southern and eastern parts of North Central Texas as a whole. In this connection, the suggestion arises that in the southern part of the general area, near the Llano-Burnett uplift, the tectonic lines which have been found to be most conspicuous in this old land mass, that is, northeast-southwest lines, govern also the folding in the Pennsylvanian rocks; whereas, farther north, and over a greater part of the whole area, the Wichita-Arbuckle alignment (west-northwest) is predominant.

The Relation of Sulphur to the Overpoling of Copper

Discussion of the paper of S. SKOWRONSKI, to be presented at the Colorado meeting, September, 1918, and printed in *Bulletin* No. 135, March, 1918, pp. 651 to 656.

PHILIP L. GILL, New York, N. Y. (written discussion*).—There is one feature of the fire-refining of electrolytic copper which I believe should be mentioned when the relation of oxygen content to the "pitch" or "set" of refined copper is under discussion; that is, the segregation of impurities. Variation of "pitch" or "set" is frequently noted in castings of different shapes, cast at the same time from the same furnace, though the oxygen content remains identical.

For instance, it is possible to cast two wire-bars in the same shaped molds from the same ladleful of copper, the one 2 in. thick showing a good level set, the other, 4 in. thick, being overpoled. Also, when two bars are cast of the same weight and at the same time from the same furnace, one bar in a copper mold at the proper temperature, the other in a mold that has been allowed to get overheated, the bar in the hot mold will show

* Received June 22, 1918.

signs of higher "pitch" or "set." Again, the temperature at which the copper is cast enters into the set of the castings. A hot copper with a high-crowned set can be quickly converted to a flat level set by lowering the temperature of the metal in the furnace by addition of a few hundred pounds of high-pitch wire-bar.

Segregation can also be noted in the fact that bars cast by pouring the metal entirely on one end show a lower set at the point of pouring than on the opposite end. If copper cast in this manner becomes overpoled, the wire-bars will show indications of overpoling first on the end opposite to the one from which they have been poured.

The difficulty of making sound copper castings in closed green-sand molds, without the aid of heavy risers, is well known to many foundry-men, and is another indication of how difficult it is to maintain the balance between the neutralizing cuprous oxide and the reducing gases absorbed by molten copper when conditions in the casting are favorable to segregation.

Referring to his Table 1, the results of melting cathode copper in 1500-gm. lots in graphite crucibles under soda ash and charcoal covers, Mr. Skowronski states that it was impossible to overpole this copper by poling with green wood. I have also experienced difficulty in obtaining samples of overpoled copper free from sulphur in small test bars, though standard 200-lb. wire-bars cast from the same melt spewed badly. I would, therefore, venture to suggest that had Mr. Skowronski been able to make a larger casting, or to eliminate the quick chill of his small test-bar mold, he would have found indications of overpoling in duplicate tests even though sulphur was not present.

Some years ago, I had occasion to make a test along somewhat similar lines. Owing to the difficulty, at that time, of obtaining accurate laboratory results on minute quantities of sulphur, in the neighborhood of our large refineries, sulphur analyses were omitted. A 100,000-lb. furnace was used and a semi-bituminous coal of exceptionally low sulphur content was selected for fuel. The cathodes charged were carefully washed twice with a finely divided high-pressure stream of warm water to remove the last traces of copper sulphate solution. The cathodes were charged and melted as rapidly as possible, care being taken to maintain an oxidizing atmosphere in the forehearth of the furnace while melting. The copper was oxidized to "set copper" and poling was begun. While poling, the metal bath was kept completely covered with clean lump charcoal. Samples were taken at approximately 10-min. intervals and analyzed for copper, the first sample being taken just before level set was reached. Poling was continued after "tough pitch" was reached and samples of the overpoled copper were carefully analyzed. Care was taken during the poling period to avoid adding fresh fuel to the fire. Results were as follows:

Sample No.	Per Cent. Cu.		Sample No.	Per Cent. Cu.	
1	99.860	low set	6	99.959	high set
2	99.890	low set	7	99.978	high ridge
3	99.934	level set	8	99.957	spewed badly
4	99.941	level set	9	99.934	spewed badly
5	99.953	slightly convex			

Samples for analysis were small flat dip samples designed to avoid segregation. Castings made for the observation of "set" were standard 135-lb. wire-bar.

Owing to the precautions taken to exclude sulphur as a factor, *i.e.*, extra washing of the cathodes, thorough oxidation of the charge, the use of charcoal as a covering for the bath, the avoidance of fresh fuel during the poling period, and the low sulphur content of the coal, the decrease in the percentage of Cu in the castings was attributed to the absorption of reducing gases from the green wood, probably CO and H, which, on segregating in the castings, were not entirely given off. The same result could, of course, have been due to the absorption of SO₂, but in this case, to have attributed the falling off in the percentage of Cu to that cause would have meant the absorption of at least 22 lb. of sulphur in approximately 20 minutes.

In conclusion, I would state that I have never found it impossible to overpole electrolytic copper under manufacturing conditions; also, that the amount of oxygen remaining in refined copper, to neutralize the effects of sulphur and other reducing gases present, will vary considerably with the amount of segregation which takes place in the casting. It also follows that castings designed to eliminate segregation will, in commercial practice, contain a higher percentage of Cu than those in which, on account of their shape, segregation is more marked.

An Interpretation of the So-called Paraffin Dirt of the Gulf Coast Oil Fields

Discussion of the paper of ALBERT D. BROKAW, to be presented at the Colorado meeting, September, 1918, and printed in *Bulletin* No. 136, April, 1918, pp. 947 to 950.

LEE HAGER,* Houston, Tex. (written discussion†).—In no other oil region of the world, perhaps, have the geological principles, of such high value in many fields, found so little practical application as in the

* President, Tidewater Oil Co.

† Received June 14, 1918.

Gulf coastal belt of Louisiana and Texas. The ever-present mantle of recent beds everywhere obscures the relations of the formations involved, and renders all questions of structure—faulting, folding, deformation—in large measure matters of conjecture.

The discovery of oil on a defined dome at Spindletop led at once to the belief that similar results would follow the exploitation of similar well known mounds. Prospecting was at once begun at High Island, Big Hill in Jefferson County, Barber's Hill, Damon Mound and other like localities. At shallow depths all encountered heavy masses of limestone, gypsum, and rock salt—conditions practically identical with those existent at the Five Salt Islands of Louisiana. In each case the porous, dolomitic cap-rock, so prolific at Spindletop was found to be either wanting or barren.

From that time, the attention of oil men was directed more and more to the secondary phenomena which general observation had shown to be present in close association with the known domes and prospective fields: seepages of oil,¹ escapes of gas, acid, and sulphureted waters, brine springs and saline flats. To the escapes of gas, being most universal, attention was chiefly attracted. These gas escapes exist in every field thus far developed in the Gulf region, with one possible exception—Hoskins Mound.

At these spots, where it is probable that gas has escaped for long ages, it was early noticed by the prospectors that certain deposits were left in the ground. Where the gases were heavily charged with "sulphur gas"— SO_2 or H_2S —streaks of free sulphur were left in the ground. Where sulphates and a little free acid were present, "sour dirt" resulted, as at Sour Lake, Hockley, Damon Mound and White's Point, among other localities.

But more common even than the above named indications was the so-called "paraffin dirt." This was probably discovered at about the same time by various parties who were digging surface holes for the purpose of burning the gas. My attention was called to this "curiosity"

¹The existence of oil seepages in the coast country has been questioned. As a matter of fact, such seepages were present in a shallow dug well on the Porcio place at Anse La Butte; at the oil spring at Sulphur Mine, where drilling had developed a little oil as early as 1872; at Vinton, where the seepage oil from wells 18 to 20 ft. in depth was sold to local sawmills; at Sour Lake, where the oil appeared in shallow dug wells at the edge of the lake, and where some oil was actually produced prior to the discovery of Spindletop; at Saratoga, where an oil spring and beds of asphalt had led to shallow drilling as early as 1862; at a spot examined by William Kennedy and by myself on the bank of Pine Island Bayou, at the north edge of the Batson field; at Hockley, where a shallow dug hole has exposed oil-saturated rock; on the Rachal ranch at White Point, where asphaltic matter occurs with much free sulphur, at the "Sulphur Hole;" and finally at Piedras Pintas, where a bed of asphalt exuding oil led to the drilling of the discovery well.

half a dozen times in the first few months after the discovery of Spindletop. I saw it in quick succession at Spindletop, Vinton, Hackberry Island, Anse La Butte, Bayou Bouillon and Jennings. The fact that it was always associated with escaping petroleum gas early favored the conclusion that it had an intimate connection with, and was probably a deposit from, the gas itself. I at first thought it to be a form of ozokerite. An analysis showed this to be an error.

The name "paraffin dirt" was given to it by Judge Douglas, of Beaumont, who dug up some of this material at a spot in Batson Prairie when gas was escaping. He organized the Paraffine Oil Co. and drilled the discovery well at this locality. These circumstances did much to attract the attention of oil men to this substance.

The characteristics of this material have been well described by Dr. Brokaw. It occurs in spots or beds from 2 to 20 ft. across. For the most part, these spots are bare of vegetation—mere wallow-like holes or depressions in the ground. The soil is resilient to the step, like rubber. When dug, the material falls apart in small squares. Intimately mixed with the soil itself, and between the cracks and joint-planes, is a yellow, jelly-like substance much resembling paraffin, or soft yellow beeswax. Where sulphureted gases are present, the stuff is blackened along the joint-planes, or shows streaks of free sulphur. In such cases, it is often slimy, and has a vile odor. When dry, a great shrinkage occurs in the mass; it lies loose in its bed, becomes a dark brown in color, and assumes a horn-like hardness.

Professor Fenneman makes mention of this substance in his report: "On the east side of the marsh (at Anse La Butte) an asphaltic substance is found, at places, about 8 in. beneath the surface of the ground. This substance so strongly impregnates the sub-soil as to give to it something of the consistency of rubber." He speaks further of an "asphaltic substance sometimes found impregnating the soil at shallow depths. . . . It is well illustrated at Anse La Butte, Sour Lake and the Tar Springs of Jasper County, Texas." It is apparent that he regards the paraffin dirt as an oil residue. The occurrence at Tar Springs is a typical asphalt bed. Both asphalt and paraffin dirt occur at Sour Lake.

For the most part, only a few small beds of paraffin dirt are found at any locality. Escaping gas is invariably present at the spots where these beds occur. That this gas is always petroleum gas, and no other, I believe the facts detailed below will go far to establish.

Matteson² says: "Concerning the paraffin dirt which Rogers mentions, that dirt has been analyzed, and we have not been able to make much out of it, except that it doesn't contain any paraffin; but where drilling has taken place in the vicinity of this paraffin dirt, the results have been a failure."

² *Bulletin* No. 136 (April, 1918), 834.

What are the facts?

It occurs in many spots at Bayou Bouillon and at New Iberia, both of which are small fields. The largest deposit of this material known in the coast country occurs at Anse La Butte. The best well in the field—5000 bbl. per day—was struck within 100 ft. of this deposit.

It occurs, again, on the Clement and Arnaudet tracts in the heart of the Jennings field. It is found in several spots in the south part of the Edgerley field surrounded by wells.

It occurs in two places on the Vincent land at Vinton, on the flat, and in the heart of the field.

It is found again in three places in the Terry field.

It occurs on the flat southwest of Spindletop—at one spot about 600 ft. from the Lucas gusher.

It occurs along the west margin of the lake at Sour Lake—again in the very heart of the field.

It is found in two or three spots in the center of the Batson field. It received its name from these occurrences.

It occurs at North Dayton. The discovery well was drilled by Judge Douglas, who opened up the Batson field.

It is present at Humble, on the Slaughter farm, on the Long and Moore tracts, and close to the discovery well drilled by C. E. Barrett—all in the oil field.

It occurs at Goose Creek, on the Minnie Gaillard, Tabb and Smith tracts, and on land owned by the writer and associates—all in the heart of the field.

It occurs in several spots on the Hogg tract in the Columbia field.

It is found at Barber's Hill in the close vicinity of all the wells which have produced any oil.

It occurs on the southwest side of the Big Hill field in Matagorda County.

It occurs, finally, at Hackberry Island, at High Island and at Pierce Junction.

None of the three last-named localities has yet produced oil, but all are well known saline domes, and have shown strong evidences of oil in a number of wells.

These localities comprise all the known occurrences of this material in the developed oil belt of the coast country. Fifteen of these localities, including practically all of the greatest fields, have produced oil in some quantity. The other three occur in connection with saline domes regarded by all oil men as possible fields. In view of these facts, Matteson's statement that, "where drilling has taken place in the vicinity of this paraffin dirt, the results have been a failure," would seem to be rather overdrawn.

It is true that in the lower Louisiana region—the Napoleonville-

Houma district—this material occurs in a number of localities. In every instance, the occurrence is connected with escaping gas. The Lirette field below Houma has yielded heavy gas wells. At three other localities wells have been drilled without results—the deepest to a depth of 2600 ft. This evidence is of a neutral character since these wells are located near the trough of a great geosyncline. If saline domes exist in this region, they are probably buried to great depth, possibly 6000 or 7000 feet.

At the Markham, White's Point, and Damon Mound fields, as well as at Hockley and Johnson's Bayou, the escaping gases are heavily charged with SO_2 and H_2S . Sulphates are formed, resulting in the presence of the so-called "sour," or "copperas" dirt. At none of these localities is any paraffin dirt found in connection with the escaping gas. If the theory of Dr. Brokaw holds good, may not this absence be due to the fact that the anaerobic organisms involved in the formation of peat are in these instances destroyed by the ferrous sulphate present? The germicidal properties of this agent are well known.

Dr. Brokaw's theory seems to offer a valid explanation of the manner in which these deposits are formed. A gas-saturated soil is requisite to prevent oxidation. Everything points to the conclusion that gas has been escaping at these paraffin spots for ages. The supply is constant and inexhaustible. Methane, where found, occurs in limited quantity and with no concentrated point of escape. Air is fatal to the necessary organisms, as is the free acid present with heavily sulphureted gases. May not all these conditions go to account for the fact that where paraffin dirt occurs petroleum gas is always present?

Several questions in connection with this theory of origin remain obscure: In what manner is the silica reduced to its hydrated colloidal condition? Experiments conducted by the staff of the Roxana Petroleum Co. indicate that no fluorine is present in the escaping gases. What, then, is the form of the alkaline agents probably requisite? Some age-long process involving the paraffin tar, the acetic acid and ammonia yielded by the decomposition of peat matter, or the potassium acetate present in the sap of many plants?

Again, these paraffin beds vary from 2 to 7 ft. in depth. They seldom exceed 10 ft. in diameter. The enclosing clays carry little organic material. If this substance is a form of peat, in what manner has it come to impregnate the surface clays to a depth of 6 or 7 feet?

Principles and Problems of Oil Prospecting in the Gulf Coast Country

Discussion of paper of W. G. MATTESON, presented at the New York meeting, February, 1918, and printed in *Bulletin* No. 134, pp. 429 to 468.

G. SHERBURNE ROGERS (written discussion*).—Mr. Kennedy's discussion¹ of Mr. Matteson's paper takes the form of a criticism of my own comments² on this paper. Mr. Kennedy is a respected authority on matters pertaining to the salt-dome oil fields, and his characterization of my "elaborate figures" as "worthless" is sufficiently candid and comprehensive to warrant a brief reply.

My "voluminous figures" consisted simply of a rough estimate of the minimum quantity of salt in the Humble dome, and a calculation of the volume of sea water and of the volume of saturated brine which this salt would represent. Mr. Kennedy apparently interprets my remarks as opposing the idea that so large a volume of salt could have been deposited from sea water, for he cites the area and thickness of European salt beds; but nothing was further from my intention. Given an arm of the sea, an arid climate, and evaporation under a hot sun, it is easy to conceive the formation of almost any thickness of bedded salt. I cited the figures in connection with Harris' theory of the origin of salt domes, according to which the plugs were formed by the deposition of salt from ascending brine solutions, owing to the drop in temperature as they neared the surface. I pointed out the well-known fact that the solubility of salt is only slightly affected by temperature, and that a drop of 80° C. would cause the deposition of less than one-tenth of the salt in solution; hence that more than ten times the volume of salt actually forming the plug must have been involved. If ten times the salt actually in sight be computed in terms of brine and multiplied by 50 or 60 to take into account all of the known salt domes, the resulting figure is so enormous that I am not at all as sure as Mr. Kennedy seems to be that the porous stratified rocks of eastern Texas and western Louisiana could contain or furnish so great a volume of migratory brine.

Mr. Kennedy, however, does not dwell on drop in temperature as the cause of the precipitation, but contents himself with ascribing the whole process to lateral secretion. As I understand it, this implies that the connate waters and brines contained in the rocks migrated to the Gulf Coast region, and there deposited their salt at various *loci* of crystallization. Just what started the crystallization or what force caused the

* Received July 18, 1918.

¹ *Bulletin* 139 (July, 1918), p. 1145

² *Bulletin* 136 (April, 1918), p. 824.

waters to migrate to these points, and there give up all their salt, is not clear; nor is it stated whether the water itself, thus suddenly deprived of its salt and made fresh, remained in the rocks or flowed out on the surface as a huge spring. Harris' idea of precipitation through loss of temperature can at least be measured in the laboratory, but the mysterious force advocated by Mr. Kennedy baffles investigation. Years of discussion by students of ore deposits failed to elucidate the mechanics of lateral secretion, or to establish its importance as a geologic process. Further argument appears fruitless, for lateral secretion would seem to be a matter of faith and, therefore, outside the realm of debate.

Mr. Kennedy also takes exception to my reference to paraffin earth as an indication of oil, and states that many "worthless wells have been drilled" because of it. Opinion as to its reliability seems to be divided³ and I did not venture my own estimate of its value; I simply stated that it should be included in any list of indications of oil. I know that it is by no means infallible; neither are salt or sulphur springs, gas seeps, or asphalt deposits, or even salt domes themselves.

³W. E. Wrather, for example, states that paraffin earth "may be classed as one of the most important indications of oil along the Gulf Coastal Plain." *Bulletin* 139 (July, 1918), p. 1152.

TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS
[SUBJECT TO REVISION]

DISCUSSION OF THIS PAPER IS INVITED. It should preferably be presented in person at the Colorado meeting, September, 1918, when an abstract of the paper will be read. If this is impossible, then discussion in writing may be sent to the Editor, American Institute of Mining Engineers, 29 West 39th Street, New York, N. Y., for presentation by the Secretary or other representative of its author. Unless special arrangement is made, the discussion of this paper will close Oct. 1, 1918. Any discussion offered thereafter should preferably be in the form of a new paper.

Radium

BY RICHARD B. MOORE,* B. S., D. SC., GOLDEN, COLO.

(Colorado Meeting, September, 1918)

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PROBABLY no other metal excites as much interest, among both scientific men and the general public, as radium. This is due partly to the high cost of radium salts and partly to the peculiar properties of the element. Since radium-bearing ores were discovered in the United States, the interest of American scientific men has been stimulated and, at the present time, more radium is extracted and refined in this country than in all the rest of the world together.

HISTORY

The property of radioactivity was discovered, partly by accident, by Henri Becquerel, the French physicist, in 1896. He was experimenting with certain fluorescent substances in order to find, if possible, a connection between fluorescence and the recently discovered X-rays. Among other chemicals which possess the property of fluorescence, he was using

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salts of uranium. His custom was to expose the fluorescent substance to the action of sunlight and then register the effect of possible penetrating radiation on a photographic plate protected from ordinary light. Becquerel's experiments gave positive results at once, and he at first believed that he had discovered a relation between fluorescence and X-rays. Later he exposed a plate to a uranium salt which had not been previously exposed to sunlight. To his surprise, on developing this plate, he found that he had obtained the same effect as he had previously secured when the uranium salt had been exposed to sunlight. The pursuit of this partly accidental discovery has given us our whole science of radioactivity. It was found that radium and its salts had the property of ionizing gases, or converting the molecules of gases into charged particles. It is this property which is used almost exclusively in identifying radioactive substances and in making quantitative determinations.

Mme. Curie, wife of the Professor of Physics in the Sorbonne, in Paris, became interested in the work of Professor Becquerel, and examined all the known elements to see whether any of them possessed properties similar to those of uranium. She found that thorium and its salts would also affect a photographic plate, without previous exposure to sunlight, and would also ionize gases. Thorium, as well as uranium, is, therefore, radioactive.

Mme. Curie found that radioactivity was an atomic property. A given weight of uranium metal had the same activity, no matter whether it was combined with chlorine, bromine, the (SO_4) radicle or the (NO_3) radicle. The other elements in combination with the uranium did not affect the activity in any way. She then made a study of radioactive minerals, paying especial attention to pitchblende, which is a natural uranium oxide containing traces of lead, arsenic, bismuth, and other impurities. This was furnished her by the Austrian Government from its mines at St. Joachimsthal. To her surprise, she found that a piece of pitchblende carrying a given weight of uranium had approximately four times greater activity than any pure uranium salt containing the same weight of uranium. This indicated that either her original conclusion that radioactivity is an atomic property was wrong, or the pitchblende contained another element, or elements, which were also radioactive. She proceeded to test these conclusions, and was assisted by the Austrian Government, which sent her a considerable amount of pitchblende for this purpose. The mineral was dissolved, and the different groups of elements were successively precipitated, each precipitate in turn being tested for its radioactivity. The lead group was found to be slightly active, and we know now that this was due to the presence of radium G, or radioactive lead. The copper group was also active, due to the presence of polonium, which, in many of its properties, is allied to bismuth. The activity associated with the iron group was due to

actinium, which is allied to some of the rare earths. The majority of the radioactivity, however, was found to be concentrated in the barium, strontium, and calcium group. The separation of the small amount of highly active material found associated with these elements was difficult and tedious. On separating the calcium from strontium, the activity still remained with the barium; and the element, radium, was finally separated by fractional crystallization of its salts, either chloride or bromide, from the corresponding barium salts.

Mme. Curie deserves great credit for the discovery of radium and for a great deal of other scientific work she has carried out with marked success in connection with this element. But those who are not versed in the subject are likely to forget to some extent what has been accomplished by those who entered the field of radioactivity after the actual discovery of radium. On the physical side, science owes an immense debt of gratitude to Sir Ernest Rutherford. It was he who beat out the pioneer path which has given us definite radioactive theories; possessed of a keen mind and a splendid intellect, his insight has been almost uncanny. Sir J. J. Thompson, W. H. Bragg, and other physicists have added to our knowledge of this side of radioactivity; while Sir William Ramsay and Professor Soddy are responsible for a great deal that has been done on the chemical side of the subject. In this country, much has been accomplished by Boltwood, Schlundt, McCoy, and Lind.

WHAT IS RADIOACTIVITY ?

Radioactive substances will affect a photographic plate and will ionize gases. This is due to the fact that radium and its salts give off three types of rays, called the alpha, beta, and gamma. The alpha rays travel with a velocity of about 20,000 miles per second and are positively charged. It was early found by Rutherford that their mass was comparable to that of a helium atom; and he definitely made the statement before the proof was actually obtained that the alpha particle was a helium atom with two positive charges on it. This was afterward proved by Sir William Ramsay and Professor Soddy, who dissolved some radium chloride in water and allowed the occluded gases to run into a spectrum tube which had previously been evacuated. On allowing these gases to stand for a day or two, the spectrum of helium gradually appeared.

The beta rays consist of negatively charged electrons, with a mass of about $\frac{1}{1600}$ th of a hydrogen atom. During radioactive changes, they are ejected with a velocity of from 100,000 to 186,000 miles per second. While the alpha particle is stopped by an ordinary sheet of note-paper, the beta particle will penetrate a thin piece of glass, but is completely stopped by a millimeter thickness of lead. All evidence points to the fact that the beta particle is similar in its properties to the electron found in a Crooks tube, and gives rise to cathode rays.

The gamma rays are not material in character but are vibrations of very short wave length in the ether. Just as the X-rays are formed in an X-ray tube by the stoppage of the cathode rays by impinging on the target, so the gamma rays are formed during radioactive changes when such changes give rise to beta rays; and these rays are expelled from the atom with the velocity of light. It is evident, therefore, that the gamma rays are practically identical with the X-rays, except that they are of shorter wave length and penetrate matter to a much greater extent.

Anything, therefore, is radioactive which gives out alpha, beta, or gamma rays, or all of them. All radioactive changes are accompanied by at least one of these rays. The elimination is due to the explosion of the radioactive atom, such explosion taking place at a definite rate, so that in the case of radium itself one-half is completely transformed in 1690 years. In the second 1690 years, half of what is left will have been changed. In the third period of 1690 years, half of what is left at the end of the second period will have been changed—and so on. The 1690-year period is called the half-life or half-value period of radium; and it can be readily seen that in 10 times the half-life period, only about 1 per cent. of the element will remain unchanged.

DISINTEGRATION SERIES

The manner in which radioactive elements change is shown in Table 1, giving the uranium series, and Table 2, the thorium series. Uranium 1 changes into uranium X_1 with the elimination of alpha rays; uranium X_1 changes into uranium X_2 with the elimination of beta rays; uranium X_2 changes into uranium 2 with the elimination of both beta and gamma rays—and so on down the list. It is thus plainly seen that the metal uranium is the parent of radium and, indeed, of all the radioactive elements which are found in any uranium mineral, and are shown in Table 1. This will correct what is a somewhat general impression that radium is the only radioactive element found in uranium ores in addition to uranium itself. Indeed, all of the elements of Table 1 are found in any uranium ore, and most of them can actually be separated chemically, and their physical and chemical properties identified.

It has already been stated that an alpha particle is a helium atom which has an atomic weight 4. Theoretically, therefore, whenever a radioactive atom explodes, with the elimination of an alpha particle, the resulting atom, left behind after the expulsion of the alpha particle, should have the atomic weight of the original atom minus 4, the atomic weight of the expelled helium atom. The atomic weight of radium has been determined experimentally as 226. The radium atom, during its change, loses an alpha particle with atomic weight 4 and, therefore, the residual radium emanation atom will have an atomic weight 222.

By examining the fourth column of Table 1, it is seen that wherever a change occurs involving an alpha particle, the atomic weight of the resulting element is reduced by 4. As the beta particle is an electron, it has not sufficient mass to affect the resulting atomic weight.

TABLE 1.—*The Uranium Radioactive Series**

Uranium Series	Half-value Period	Rays	Atomic Weight
Uranium 1.....	5×10^9 years	alpha	238
Uranium X ₁	24.6 days	beta	234
Uranium X ₂	1.15 min.	beta and gamma	234
Uranium 2.....	2×10^8 years	alpha	234
Ionium.....	10^4 years	alpha	230
Radium.....	1690 years	alpha and slow beta	226
Radium emanation.....	3.86 min.	alpha	222
Radium A.....	3.0 min.	alpha	218
Radium B.....	26.8 min.	beta and gamma	214
Radium C.....	19.5 min.	alpha, beta and gamma	214
Radium D.....	16.5 years	beta and gamma	210
Radium E.....	5.0 days	beta	210
Radium F.....	136 days	alpha	210
Radium G (lead).....	.....	.....	206

* The branches of Tables 1 and 2 are omitted for the sake of simplicity.

TABLE 2.—*The Thorium Radioactive Series*

Thorium Series	Half-value Period	Rays	Atomic Weight
Thorium.....	1.5×10^{10} years	alpha	232
Mesothorium 1.....	5.5 years	beta	228
Mesothorium 2.....	6.2 hr.	beta and gamma	228
Radiothorium.....	2 years	alpha	228
Thorium X.....	3.65 days	alpha	224
Thorium emanation.....	54 sec.	alpha	220
Thorium A.....	0.14 sec.	alpha	216
Thorium B.....	10.6 hr.	beta and gamma	212
Thorium C.....	60 min.	alpha and beta	212
Thorium D ₁	3.1 min.	beta and gamma	208
Thorium D ₂ (lead).....	10^4 years	beta	208

There is some definite experimental proof that the above statements are correct. Sir William Ramsay and Professor Soddy actually determined the density of the radium emanation, and the figure obtained as a mean of five determinations was 223. In addition, lead is always found in uranium minerals, and the atomic weight of radium G, or the

final disintegration product, according to theory, is 206. This does not coincide with the atomic weight of ordinary lead, which is 207; but some experimental work on the atomic weight of lead obtained from uranium and thorium minerals, by Professor F. W. Richards, O. Hönigschmid and Professor Soddy, has shown that the atomic weight of uranium lead is 206, while that of thorium lead is 208—an exceedingly interesting experimental confirmation of the theory. We have, therefore, actually three forms of lead, the only difference among them being their densities, each one having exactly the same chemical and physical properties. If they were mixed by fusion, no known method could separate them; and the only way of telling one from another would be by making an actual density determination.

There is another radioactive series called the actinium series, which is very similar to the uranium series, but as it is of less importance it is not discussed in this paper.

RADIUM ORE DEPOSITS

The two principal commercial ores of radium are pitchblende and carnotite. The former mineral has no definite composition, consisting of uranium oxides (UO_3 , UO_2) with oxides of lead, calcium, iron, bismuth, manganese, copper, silicon, aluminum, and rare earths. Carnotite has a more definite composition, being a potassium uranyl vanadate containing small quantities of barium and calcium. The formula $\text{K}_2\text{O} \cdot 2\text{UO}_3 \cdot \text{V}_2\text{O}_5 \cdot 3\text{H}_2\text{O}$ expresses its composition fairly well, although not exactly. Of lesser importance are autunite, a hydrated calcium uranium phosphate $\text{Ca}(\text{UO}_2)_2(\text{PO}_4)_2 \cdot 8\text{H}_2\text{O}$, and torbernite, a hydrated copper uranium phosphate $\text{Cu}(\text{UO}_2)_2 \cdot \text{P}_2\text{O}_8 \cdot 8\text{H}_2\text{O}$.

St. Joachimsthal

The pitchblende deposit at St. Joachimsthal, Austria,¹ is in mica schist interbedded with lime schist and crystalline limestone. Toward the east and northeast the formation is gneiss. The gneiss was intruded by quartz porphyry subsequent to the deposition of the vein material. In the mica schist are fissures filled with volcanic material which cut the mineralized zone at various points and depths. The veins are usually 6 in. to 2 ft. wide, in rare cases widening out to 3 ft. The mode of mineralization varies greatly, the ores occurring in both stringers and pockets. They contain the following metals: Silver, metallic, and as argentite, polybasite, tetrahedrite, etc.; nickel, as nickelin, chloanthite, etc.; cobalt, as smaltite, bismutosmaltite, etc.; bismuth, as metallic

¹ Richard Beck: *Lehre von den Erzlagern*. 3d Ed., 1, 408-410. Berlin, Borntraeger, 1909.

Richard Beck: *The Nature of Ore Deposits*. Translation by W. H. Weed. 1st Ed., 1, 284-287. New York and London, *Engineering and Mining Journal*, 1905.

bismuth, bismite, etc.; arsenic, as metallic arsenic and arsenopyrite; and uranium, as pitchblende and other alteration products. Galenite, zinc blende, pyrite, marcasite, and copper occur in minor quantities.

The veins show that deposition occurred in three periods: the cobalt and nickel were deposited first, then the uranium, and lastly the silver. Dolomite spar is always present, and generally has a white or yellowish-white color, but changes to a brownish-red hue where pitchblende begins to appear, and is a dirty gray where it is actually in contact with the ore. Deep-blue fluorspar is always present.

The mines at Joachimsthal have been worked since 1517. In 1545 the production of silver ores declined considerably, but since then the deposits have been mined for bismuth and cobalt. During the last 25 years the mines have been worked for uranium.

Saxony

In the vicinity of Annaburg, on the Saxony side of the Erzgebirge, the silver-cobalt veins resemble those at Joachimsthal. At Johanngeorgenstadt, the veins contain tin and silver-cobalt ores. Where dolomite spar is found, the silver-cobalt ores contain pitchblende, as at Anna-berg. In the Gottessegen mine the pitchblende occurs in the spar in pieces 2 to 3 in. in diameter. These mines are worked principally for bismuth ocher, but also for cobalt and nickel.

In the cobalt-bismuth mines of Schneeberg, are found bismutite and various minerals of nickel, silver, and arsenic. There is also some pitchblende, uranochalcite, uranospinite, galenite, zinc blende, etc.

Cornwall

Pitchblende has also been found in Cornwall, England, in the tin region. As at Joachimsthal and Johanngeorgenstadt, the mineral is found associated with nickel-cobalt veins, although only part of the veins are highly argentiferous. Even though these veins are closely connected with the tin veins, they apparently are not of the same age as the latter, but belong to the same general period of mineralization. According to Ussher, Barrow and MacAllister,² the most important uranium producers are the South Terras mine, the Carharrack, Dolcoath, Wheal Unity, Wheal Gorland, Wheal Lovell, and Trenwith. The South Terras mine is situated in the valley of the Fal, southwest of St. Austell. The country rock is slate, intruded by greenstone and granite porphyry dikes.

Pitchblende in the United States

Pitchblende has been found in the following localities in the United States: Feldspar quarry, at Middletown, Conn., in large octahedrons;

² The Geology of the Country Around Bodmin and St. Austell. *Memoirs of the Geological Survey of England and Wales* (1909), 157.

in Hall's quarry, at Glastonbury, Branchville, Conn., in a pegmatite vein and usually embedded in albite; at Marietta, S. C.; in the Baringer Hill district, Llano County, Texas; in the Bald Mountain district, Black Hills, S. Dak.; in Mitchell County, N. C.; and in Gilpin County, Colorado. The latter district is the only one of commercial importance.

All of the Gilpin County mines, with one exception, are found on or near Quartz Hill, a few miles from Central City. There are five that have produced pitchblende in quantity: the Kirk, Wood, German, Belcher, and Calhoun. The Kirk, Belcher and German mines are close together on Quartz Hill, the Wood and the Calhoun being in the valley below.

These mines, until recently, have been worked mainly for gold. In this district, gneiss and crystalline schist predominate, with intrusive andesitic dikes and occasionally acid granitic dikes. The rock containing the pitchblende, galena, sphalerite, etc., is a fine-grained aplitic granite which probably once contained an appreciable amount of biotite. The ore deposits are of two general types, one containing pitchblende with pyrite, sphalerite and galena, and sometimes marcasite; the other type contains pyrite, chalcopyrite, sphalerite and galena, with some gold and silver. Generally speaking, the two types are not associated, so that the miner has a choice of mining either for pitchblende, or for gold.

The Kirk mine has probably been the most important producer of the five mentioned although reliable data on the output of pitchblende from this mine, up to a few years ago, has been difficult to obtain. During the last 12 years, about 20 tons of ore, with an average content of 35 per cent. U_3O_8 , and over 100 tons with a content of 3 to 4 per cent. U_3O_8 , have been mined. The mine has been shut down for some time. More recent operations of the German and Belcher mines produced 120 tons of low-grade ore, averaging about 1 per cent. U_3O_8 , and 6 tons of high grade. Smaller quantities of ore have been produced at various times from these mines and from the Wood and the Calhoun.

Australia

Uranium ores are found in certain localities in Australia. One of these deposits is 80 miles east of Farina, a railroad station on the Great Northern line in South Australia, and lies between Mount Painter and Mount Pitt. H. L. Y. Brown³ states that the rocks of the district consist of coarse and fine feldspathic, siliceous, and micaceous granite, gneiss, quartzite and mica schist. The rocks are contorted in places and penetrated by dikes of coarse, pink-colored eruptive granite.

Two of the prospect pits are on outcrops of iron oxide with cellular quartz and gossan, the whole having the appearance of an irregular lode. The uranium minerals, torbernite and autunite, are disseminated

³ Occurrence of Uranium Ores and other Rare Minerals near Mount Painter, in the Flinders Range of South Australia. South Australia, Mines Dept., 1911.

through the ore, and are also crystallized on the walls of the fissures and cavities in it. Uranophane and gummite occur sparingly; fergusonite and some monazite are also present. Another uranium deposit lies southeast of the one just described, about 20 miles southeast of Olary, on the railroad line from Petersburg to Broken Hill, South Australia. The ore occurs as a yellow and greenish yellow incrustation and powder on the faces, joints and cavities of a lode, which consists of titaniferous magnetite, magnetite, etc., and quartz in association with black mica.

Portugal

Autunite is found in commercial quantities in Portugal in the district between the towns of Guarda and Sabugal. An excellent description is given by Segaud and Humery.⁴ Apart from the uranium, the rocks of the region are much mineralized, showing deposits of galena, arsenopyrite, chalcopyrite, tungsten and cassiterite.

All of the deposits referred to above are important and have been developed as commercial sources of radium; in fact, until about 7 years ago, they were the only sources from which radium ores were obtained.

Carnotite Deposits of Colorado and Utah

About 1910, the carnotite deposits of southwestern Colorado and eastern Utah began to receive attention. They were known as far back as 1881, but the composition of the ore was unknown until 1897. In 1899, an analysis showed that the ore not only contained uranium, but was a potassium uranyl vanadate.

In 1900, a small plant was erected in the McIntyre district, south of the Paradox Valley, Colo., for the extraction and recovery of uranium oxide from carnotite ore. Only moderate success was achieved, and the plant was shortly shut down. Operations were also started by other concerns, notably the Western Refining Co. and the Dolores Refining Co.; these plants extracted uranium and vanadium only. None of these operations was of importance, and it was not until 1909 to 1910 that any interest was shown in the carnotite deposits as a source of radium. At that time, the ore was almost exclusively shipped abroad.

In the fall of 1912, representatives of the U. S. Bureau of Mines made a thorough survey of the carnotite fields and announced the fact⁵ that the carnotite deposits of Colorado and Utah constituted by far the largest source of radium-bearing ores in the world. Developments since that time have proved this statement to be correct, as the larger part of the radium that has been produced in the world has been derived from American carnotite ore.

⁴Segaud et Humery: *Les Gisements d'Uranium du Portugal. Annales des Mines, Mémoires*, Ser. 11 (1913), 3, 111-118.

⁵Richard B. Moore and Karl L. Kithil: *A Preliminary Report on Uranium, Radium and Vanadium. U. S. Bureau of Mines Bulletin No. 70* (1913).

The deposits are found mainly in Dolores, San Miguel, and Montrose Counties, Colorado, and extend over a belt about 60 miles long by 20 miles wide. The ore is also found to the west of the La Sal Mountains in Utah, and along the San Rafael Swell, southwest of Green River, Utah. Small patches of ore are found scattered between these points and extend as far north as Meeker, Colorado.

The most usual ore is a sandstone so impregnated with yellow carnotite that the color is decidedly noticeable, and contains small kidneys of brown sandy clay. The kidneys constitute a considerable part of some of the ore; in many cases they are thinly scattered through the sandstone. Although ore of the character mentioned is widely distributed in the Paradox and adjacent districts, and constitutes a large part of the ore shipped, it is by no means the only ore of commercial importance. Indeed, the variety of the types of ore here and in Utah is one of the interesting features of the uranium and vanadium deposits. There are dark blue, brown, and black vanadium ores, the dark blue ores being lustrous when first mined and usually carrying uranium; high-grade carnotite in vug holes so soft that it can be molded in the fingers; and the same kind of ore crystallized with gypsum. Red calcium vanadate is found alone and mixed with carnotite. The ores of the Paradox district differ in many respects from those in Utah, but chiefly in carrying larger proportions of carnotite, and as a rule are more yellow. Not only do they carry more uranium but also, on the average, more vanadium, although individual shipments from Utah, particularly from Temple Mountain, might seem higher in vanadium than the average ore from the Paradox district.

The deposits are invariably pockets, many of which, however, are of considerable size. A few individual claims have produced as high as 500 tons of shipping ore, which, however, is exceptional. The ore is found in a light-colored sandstone overlain in places with shale and conglomerate; according to Hillebrand and Ransome, this is the McElmo formation.⁶

METALLURGICAL TREATMENT

The average commercial ore from which radium is extracted contains from 5 to 10 milligrams of radium element per ton of ore. Allowing for losses in extraction and recovery, it takes about 5000 or 6000 tons of ore to give an ounce of radium element. It can be seen, therefore, that the metallurgical processes involved in the extraction of radium are entirely different from those connected with any other element. There are two general steps which must be carried out: first, to obtain

⁶ W. F. Hillebrand and F. L. Ransome: On Carnotite and Associated Vanadiferous Minerals in Western Colorado. *U. S. Geological Survey Bulletin No. 262* (1905), 11.

a radium concentrate from the ore; and second, the re-treatment of this concentrate in order to extract a high-grade product. The first step is necessarily carried out on a large scale, while the major part of the second step is done in the laboratory.

The different methods of treating radium-bearing ores to obtain a concentrate may be classed under three general heads: (1) an alkaline leach, followed by an acid leach; (2) fusing the ore with some material that will disintegrate it and make the extraction of the valuable contents possible; (3) an acid leach.

1. *Alkaline Leach Methods*

It is probable that some of the early experimental work on extracting radium from carnotite ore involved boiling the ore with a solution of sodium-carbonate, thus getting rid of the uranium and vanadium, which go into solution. Since radium has properties similar to those of barium, any radium in the ore would be converted into radium carbonate, and on treating the residue with dilute c. p. hydrochloric acid, the radium would be dissolved with any other acid-soluble products.

The radium concentrate always obtained is radium-barium sulfate. By adding barium chloride and sulfuric acid, or sodium sulfate, to the slightly acid solution carrying the radium, barium sulfate is formed in the solution and drags down radium sulfate with it. The radium is almost always precipitated in this manner in a liquor sufficient in volume to hold it actually in solution. Undoubtedly adsorption has something to do with the precipitation of the radium along with the barium sulfate, but this does not fully explain the small losses that accompany such precipitation. The term "pseudo-isotopy" has been given to this property by Dr. S. C. Lind.⁷

The general principles outlined above are included in the Haynes-Engle process, which involves boiling the ore with an alkaline carbonate solution. The object of this process was to recover uranium and vanadium only, and did not attempt to obtain the radium in any form. A patent taken out by Warren F. Bleeker involved the extra step which the Haynes-Engle process did not cover, namely, the leaching of the residues with hydrochloric acid in order to obtain the radium in solution, after the ore had been boiled with an alkaline carbonate solution.

The alkaline leach method has many advantages and some disadvantages. It separates the uranium and vanadium from the ore during the first stage of the process. It eliminates sulfates by converting the metallic sulfates in the ore into metallic carbonates and soluble sulfates, which go into the filtrate with the uranium and vanadium. The radium,

⁷ S. C. Lind, J. E. Underwood, and C. F. Whittemore: The Solubility of Pure Radium Sulfate. *Journal of the American Chemical Society* (March, 1918), **40**, 465-472.

therefore, is left behind in the residue as carbonate, practically free from sulfates. This prevents the re-precipitation of the radium as sulfate, on treating with acid, until after the acid solution is filtered from the tailings. On the other hand, it has the following disadvantages: It converts some of the silica in the ore into sodium silicate, which makes filtration very difficult—in fact, most of the filtering and washing has to be done by decantation. It is difficult to treat concentrates obtained by this process, as these are almost invariably of very fine mesh, which adds to the filtration difficulties. The treatment with alkaline carbonate converts most of the iron and a good part of the aluminum in the ore into an acid-soluble form, so that the acid consumption is high. The method, however, can be used with success for the treatment of certain uranium ores, particularly carnotite, autunite, and torbernite.

2. *Fusion Methods*

The first method used for the extraction of radium was fusing pitchblende ores with sodium sulfate. This method was originally used by the Austrian Government in connection with the treatment of pitchblende ores from its mines in St. Joachimsthal. By this fusion, the uranium in the ore is changed to sodium uranate, which can be dissolved from the insoluble residue, after leaching out the excess of sodium sulfate with water, by dilute sulfuric acid. The radium remains behind with the residue and, before the discovery of radium, was discarded. Afterward, the residue was boiled with sodium carbonate, which converted a portion of the radium sulfate into radium carbonate, and this was leached out with dilute hydrochloric acid. After repeating this process several times, practically all of the radium was leached from the residue, and the acid leaches were combined. Barium sulfate was then precipitated in the acid solution in the ordinary manner, and in this way the radium was obtained as a concentrate with the barium sulphate.

A somewhat similar treatment is given to the ores from Olary, South Australia, by the Radcliffe process. The main uranium mineral is carnotite, but this is associated with considerable quantities of ilmenite and other rare-earth minerals that are not found in American carnotite. The concentrates are mixed with three times their weight of salt-cake, and fused in a reverberatory furnace; the fused product is then crushed and agitated in wooden vats, with water. By suitable adjustments it is possible to separate on the bottom of the vats a considerable amount of comparatively coarse material that is almost free from radium and uranium. The turbid overflow carries in suspension the radium, lead, and barium, as sulfates, together with a considerable amount of finely divided silica. The overflow is pumped to large lead-lined tanks and allowed to stand all night. This is nothing but a sliming process and has the advantage that the radium in the form of sulfate always remains with

the fine material. The slimes settle completely in 12 hr. and are collected periodically and treated for the recovery of radium.

The process of Schlundt, which is being used by one company in the United States in connection with carnotite, is very similar to the Radcliffe process. The ore is fused with acid sodium sulfate, leached and washed with water to extract the uranium, vanadium, and other soluble products, and the residue is slimed in order to obtain a crude concentration of the radium, which stays with the fine material.

The U. S. Bureau of Mines has found that if a radium-barium sulfate high in silica is fused with caustic soda containing a small quantity of sodium carbonate, the silica can be easily washed out as sodium silicate, while the barium and radium remain behind as radium-barium carbonates, which can be readily dissolved in hydrochloric acid. Usually the commercial caustic soda contains enough carbonate without the addition of an extra amount. This method has been applied commercially to the treatment of crude concentrates, such as are obtained by the Schlundt process.

One firm has used a sodium carbonate fusion. The ore is fused with soda ash, usually about $2\frac{1}{2}$ times the weight of the ore being required. This is done in a reverberatory furnace, lined with magnesite brick, and the fused mass is run directly into vats, in which it is leached. The silica is thus converted into sodium silicate and so passes into solution, together with the uranium and vanadium. The iron, calcium, barium, radium, etc., remain as the insoluble residue, which is washed in filter presses. This material is then treated with dilute sulfate-free hydrochloric acid, which dissolves the carbonates, and the radium and barium are precipitated by the addition of the requisite amount of sulfuric acid, or sodium sulfate. The whole is allowed to stand in settling tanks and the clear liquid is drawn off, leaving the barium-radium sulfates, mixed with a considerable amount of silica and other impurities, as a sludge at the bottom of the tank. This is taken off without previous filtration, and dried, forming a crude radium-barium sulfate, which is then refined.

The main advantages of this method are that it will treat an ore containing considerable quantities of sulfates, as the process removes the sulfates as soluble sodium sulfate in a similar manner to the alkaline leach method. In addition, it is applicable to the treatment of concentrates, as fineness of material is really an advantage instead of a disadvantage, as it does not involve any "sliming." The main disadvantage is the cost, both for the chemicals and the labor required. The concentrate obtained is also low-grade, which involves additional refining costs.

3. Acid Leach Methods

Leaching with hydrochloric acid gives an excellent extraction, provided the ore is comparatively free from sulfates. As a considerable propor-

tion of such ores contain traces of gypsum, it is a method which must be used on selected ores. A hydrochloric acid leach has been used successfully on Cornish pitchblende, which is practically free from pyrite, but is not applicable in any way to American pitchblende, which contains considerable quantities of pyrite. It has also been used on Portuguese autunite. In general, the hydrochloric method is applicable to certain ores, but has a limited use.

Leaching with nitric acid has been used more successfully. This is the method originated by the U. S. Bureau of Mines^a and used in the plant of the National Radium Institute. As is generally known, barium sulfate is much more soluble in nitric acid than in hydrochloric acid, and this is especially true when the nitric acid is concentrated and hot. For this reason, ores containing sulfates can be successfully treated by a nitric acid leach, and the method has been successfully applied to ores carrying as much as 1 per cent. gypsum. On ores carrying small quantities of sulfates, the extraction obtained is very high, frequently going, on a commercial scale, to 93 and even to 95 per cent. Boiling, 40-per cent. nitric acid is used, and filtration is obtained on either a vacuum or a pressure filter. Filtration must be done rapidly, because, as the acid cools, the radium has a tendency to precipitate out, especially in the presence of sulfates. During the process of recovering uranium and vanadium by this method, practically nothing but sodium hydroxide and sodium carbonate are added to the nitric acid. Consequently, sodium nitrate is obtained as the final product after the precipitation of the radium, uranium, and vanadium; and this sodium nitrate is recovered by evaporation and crystallization and used over again for the manufacture of nitric acid in the ordinary way. The average losses of nitric acid were about 15 per cent., so that 85 per cent. of the acid used was recovered as sodium nitrate. This actually reduced the cost of the nitric acid below that of hydrochloric, and this, together with the high extraction of the radium obtained, was largely responsible for the low cost of the recovered radium and the success of the method.

The process cannot treat successfully ores carrying as large quantities of gypsum as can be treated by some of the other methods, such as the sodium carbonate fusion, but it is applicable to a very large percentage of the carnotite ore produced. Difficulty was experienced in treating concentrates, most of which are below 150 mesh. As already stated, it has been necessary to filter rapidly in order to get a good extraction; and the problem of filtering a 40-per cent., boiling nitric solution, containing fine material in suspension, was found to be difficult. It was finally overcome by the development and use of a pressure filter instead of a

^a Charles L. Parsons, R. B. Moore, S. C. Lind, and O. C. Schaefer: Extraction and Recovery of Radium, Uranium, and Vanadium from Carnotite. *U. S. Bureau of Mines Bulletin* No. 104 (1915).

suction filter; this consisted of a steel shell containing an earthenware filter set in concrete. The earthenware filter had at its bottom, as filtering medium, a plate of either filtros or alundum. The steel top was made tight with swing bolts, and a pressure of 100 lb. was applied.

Refining

The radium-barium sulfate concentrate obtained in a satisfactory metallurgical process should carry about 1 mg. of radium element per kilogram of concentrate, a ratio of one to a million. The next step is to get this concentrate back into solution. The most successful method is to reduce the sulfate with about one-sixth its weight of pulverized charcoal in a furnace at a temperature from 800° to 900° C. In the presence of silica, the reduction takes place slowly and is not complete; but if the sulfate does not contain more than from 5 to 10 per cent. silica, the reduction may reach 90 per cent. or more. The radium-barium sulfides are then dissolved in sulfate-free hydrochloric acid, and filtered. From this stage on, the refining process is simply one of fractional crystallization. Radium chloride and bromide are less soluble than the corresponding barium salts; the crystals first obtained on evaporation are therefore richer in radium than the mother liquor from which they are obtained. The difference in solubility of the bromides is considerably greater than that of chlorides; at some stage in the process, all of the chloride salts are converted into bromides, after which fractionation is continued as bromide, in hydrobromic acid solution. The factor of separation is higher in acid than in neutral solution; it is customary, therefore, to fractionate both chlorides and bromides in acid solution. Full details of the methods of fractionation are given in U. S. Bureau of Mines *Bulletin* No. 104.⁹

METHODS OF ORE CONCENTRATION

Both wet and dry methods of concentration may be used for carnotite ores. The wet method simply involves crushing the ore and agitating with water in a manner that will best separate the fine-grained particles of carnotite from the coarser silica particles. After allowing to settle, the fine material can be slimed off and run into settling tanks, while the coarser tailings are re-treated. The only successful method of dry concentration that has so far been used has involved the Raymond pulverizer and dust collecting system. The National Radium Institute built a small plant near the claims it was working in Long Park, Colo., and gave the method a thorough testing, with excellent results.¹⁰ The

⁹ *Op. cit.*

¹⁰ Karl L. Kithil and John A. Davis: Mining and Concentration of Carnotite Ores. U. S. Bureau of Mines *Bulletin* No. 103 (1917).

capacity of the mill was a little over one ton of milling ore an hour; and the average output was 365 lb. of concentrate an hour. The milling ore had an average content of 0.85 per cent. U_3O_8 ; the average of all concentrates was 2.92 per cent. U_3O_8 ; the tailings averaged 0.3 per cent.; the ratio of concentration was about 6 to 1. As much as 63.7 per cent. of the carnotite contained in the milling ore was extracted, and 60 per cent. of all the carnotite in this ore was actually recovered in the concentrates.

FUTURE SUPPLY OF ORE

It is difficult to estimate the exact amount of radium in existence at the present time; probably it is somewhere around 3 oz. of radium element. On account of the great scientific interest attached to radium, and on account of its use in the war and in medicine, the permanency of the ore supply is an important question. Considerably more than half the amount of radium now in existence has come from Colorado and Utah carnotite ores. Six years ago, the engineers of the Bureau of Mines estimated that, at the current rate of production, the deposits might last, commercially, 10 or 12 years. At the present time, it is very difficult to obtain ore. Most of the deposits are owned by five operating radium companies. The production has increased very greatly during the war; and the author is very doubtful whether we can depend upon our carnotite deposits to yield commercial quantities of ore for more than 6 or 7 years longer. It is his judgment that the fields will not produce more than 100 additional grams of radium element at the most—if that much. This would about double the world's present supply; but, on account of the large use of radium in cancer treatment, such an amount, although large scientifically, would be small in proportion to the probable demand.

TABLE 3.—*Radium Production from American Carnotite*

Year	Tons U_3O_8	Tons U	Grams Ra Contained	Grams Ra Recovered, (75% Basis)
1912	28.8	24.4	7.4	5.5
1913	41.0	34.8	10.5	7.9
1914	87.2	74.0	22.5	16.9
1915	23.5	19.9	6.0	4.5
1916 ^(a)				
1917	70.0	59.3	18.0	13.5

(a) Official statistics are not available for 1916.

USES OF RADIUM

The use of radium in cancer research has extended over a period of several years. Some very remarkable results have been obtained, especially recently in the treatment of certain forms of cancer. A large

number of permanent cures have been effected; and whereas the medical fraternity was skeptical at first, a great deal of the opposition has been overcome, and several of the largest and most prominent hospitals in the country are now supplied with considerable quantities of radium for cancer treatment. A word of warning must be given in this connection. The successful use of radioactive waters and low-grade radium preparations is doubtful and should be carefully distinguished from the successful results obtained with considerable quantities of high-grade radium salts. Naturally, there have been some attempts to foist on the public, at a high price, low-grade preparations, the value of which is, to say the least, very uncertain.

The chief technical use for radium is in connection with permanently luminous paint. If radium salts are mixed with phosphorescent zinc sulfide, a product is obtained which is permanently luminous in the dark without previous exposure to light. The zinc sulfide must be specially prepared and usually contains traces of impurities, such as copper, manganese, etc. Just what relation exists between these impurities and the peculiar properties of the zinc sulfide is not known, although experimental work is now being done to determine it. The luminous paint usually carries from 0.1 to 0.25 mg. of radium element to 1 gm. of zinc sulfide, depending upon the particular use of the paint.

This material is now being largely used on the faces of watches and clocks; to coat electric light push-buttons and the chains attached to electric globes; and for various other purposes. It is a great pity that our supply of radium is being disseminated in this manner. But as the physicians and surgeons of the country are not purchasing enough radium to make the industry a financial success, it is natural that the manufacturers should take other means of creating a demand. The day is not far distant, in the judgment of the writer, when we shall greatly regret the radium that has been lost in this way.

Radium has a most decided usefulness at the present time; nine instruments used on airplanes have dials made luminous with radium paint; it is employed in the same manner for compasses and gunsights. The efficiency of night firing, with both machine guns and artillery, has been greatly increased by the use of these luminous sights. Other uses cannot be specified, at the present time, in a public paper.

MESOTHORIUM AS A SUBSTITUTE FOR RADIUM

One way of preventing the dissemination and loss of radium is to provide a substitute. Mesothorium (see Table 2) is an excellent substitute in many ways. Its half-life period is much shorter than that of radium. When first prepared, it gradually increases in activity, comes to a maximum, and then begins to lose its activity. After "ripening"

for about a year after being prepared, it can be used for luminous paint just as efficiently as radium. Its usefulness for such purpose will last for 4 or 5 years, which is as long as is required for cheap watches, push-buttons, etc. Mesothorium can be obtained as a byproduct in the treatment of monazite sand for the manufacture of thorium nitrate used in incandescent mantles. During the last year, the U. S. Bureau of Mines has been experimenting along these lines and has developed a process which is being put into the largest thorium plant in the country at the present time, and it is hoped that before long mesothorium can be substituted for some of the radium that is now being used in luminous products. Mesothorium can also be used for cancer treatment, although its short life makes it much less desirable for this purpose than radium.

DISCUSSION OF THIS PAPER IS INVITED. It should preferably be presented in person at the Colorado meeting, September, 1918, when an abstract of the paper will be read. If this is impossible, then discussion in writing may be sent to the Editor, American Institute of Mining Engineers, 29 West 39th Street, New York, N. Y., for presentation by the Secretary or other representative of its author. Unless special arrangement is made, the discussion of this paper will close Oct. 1, 1918. Any discussion offered thereafter should preferably be in the form of a new paper.

Molybdenite Operations at Climax, Colorado

BY D. F. HALEY, B. S.,* DENVER, COLO.

(Colorado Meeting, September, 1918)

THE molybdenite deposits at Climax, Colo., have recently attracted considerable notice, because of their great size, as compared with other known deposits of the same mineral.

Climax station, on the Colorado Southern narrow-gage railway, was at one time the Fremont Pass station on the Denver & Rio Grande. It is $14\frac{1}{2}$ miles northeast of Leadville, and exactly on the divide between the headwaters of the Arkansas and Blue Rivers. Climax station is 11,300 ft. (3444 m.) above sea level. The working tunnel of the molybdenum mine is about 1 mile from the railroad, and 900 ft. above it, at an elevation of 12,200 feet.

The climatic conditions are severe, and snow can be expected during any month of the year. Winter sets in not later than Nov. 1, the snowfall is very heavy, and the ground remains covered with snow until June 1, and sometimes even later. From June 1 to Oct. 1, there is much rain and a little snow falls in the late afternoon nearly every day. In October, 1917, there was one of the biggest snowstorms and blizzards of the year. Being just on the divide, constant strong winds blow the fine, dry snow with such force that, during most of the winter, outside work of any kind is accomplished under most trying conditions.

Within a few miles of Climax, some of the richest gold placers of Colorado occur. One of them, McNulty Gulch, was just across on the northeastern flank of Bartlett mountain. This mountain, therefore, was well prospected, and the presence of a bluish mineral and a yellowish one resembling sulphur was known to the old prospectors. They thought for many years that the blue mineral was graphite, and it is difficult to say when it first became definitely known that it was molybdenite. Claims had been staked as early as 1896, but it is evident that the prospectors at that time were looking for gold. In 1902, several claims were acquired by H. Leal, who drove a tunnel about 900 ft. (274 m.) long, probably to intersect a fault, which shows on the surface, and was thought to be a possible gold carrier. Gold was not found in paying quantities, but throughout its length the tunnel passed through a fractured silicified granite, showing a fairly uniform distribution of a fine-grained bluish mineral, which was finally determined as molybdenite. For several

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years no work was done on the property, although it had been examined by several engineers.

In 1916, the property was brought to the attention of the Denver office of The American Metal Co., Ltd., whose engineers made a thorough examination. They recognized the extent of the deposit and its tonnage possibilities, but had great difficulty in getting concordant results from the different assayers to whom their samples were submitted, the values varying between 0.4 and 1.2 per cent. Pop shots were then put into the sides of the tunnel for its entire length, and the ore was broken down on canvas. In addition, three short crosscuts were run east and west from the tunnel, and car samples were taken from the broken muck. The ore thus obtained was cut down to a ton sample and sent to the General Engineering Co. at Salt Lake. After the usual preliminary tests, the whole sample was put through flotation machines and a concentrate was obtained, assays of which showed concordant results, and indicated that a recovery of 12 lb. of MoS_2 per ton of ore could reasonably be expected.

GEOLOGY OF THE DEPOSIT

The orebodies thus far exposed are found on the southwestern slope of Bartlett mountain, which forms the northern spur of a horseshoe-shaped glacial cirque, the southern spur of the horseshoe being Mt. Ceresco. Both of these mountains consist of alaskite, or highly siliceous granite. The high ridge forming the cirque is a coarsely crystalline biotite-gneiss. The alaskite is unquestionably an intrusion into the gneiss, and the latter at one time probably covered the whole area, but has been eroded from Bartlett and Ceresco mountains. In the alaskite, many inclusions of the gneiss are found; one inclusion several feet in diameter has been found in the tunnel workings 350 ft. (106 m.) below the surface. On the western flank of Bartlett mountain, thick limestone beds are found, tilted at such an angle as to indicate that they at one time covered the area but have been removed by erosion. The gneiss may be an altered sedimentary rock.

Glacial action has been severe, and the divide is covered by a heavy moraine. Great boulders of alaskite containing molybdenite are found in the moraine, for at least 2 miles from Bartlett mountain. At the base of the mountain, several hundred thousand tons of talus have collected, which carries commercial quantities of MoS_2 , and will be milled.

The ore occurs as an intricate system of fine stringers quite evenly distributed throughout the alaskite. The original granite has been much altered and silicified, and appears now to consist only of a quartz ground-mass in which some phenocrysts of feldspar still remain. Throughout the main ore-bearing rock are found masses of a typical quartz-porphyry; it is not yet determined whether this is a segregation or a later intrusive. It is significant that very little ore mineral is found in the quartz-

porphyry. The greater portion of the ore is found in tiny veinlets, crisscrossing the alaskite, and showing out clearly from the light ground-mass. At the center of each veinlet very fine grains of molybdenite are visible to the eye, but toward the edges the grains become so fine as to appear simply as a dark coloration.

The orebody has not yet been thoroughly studied with reference to its genesis. It is believed, however, that when the igneous granite mass was intruded into the overlying gneiss and sediments, an outer shell was formed, due to rapid cooling of the intruding magma. Shrinkage cracks and fractures were formed in the shell by this quick cooling, and the cracks were then filled with silica and molybdenite expelled as a final phase of the cooling magma. The whole granitic mass carries considerable iron pyrite as crystals and films, part of which was probably an original constituent of the granite. Many large fractures occur, running in all directions, with no apparent relation to one another. Along them a considerable amount of oxidation has taken place, the iron and molybdenite being wholly changed to oxides; the oxidation is still prominent down to 350 ft. (106 m.) below surface. A foot or so away from a fracture, however, oxidation has ceased. The molybdenite is fine grained, very little flaky material being found, which is unusual for this mineral.

The only associated minerals are iron pyrite and a very small amount of copper. Occasionally a small pocket of hübnerite is found, but not in appreciable amounts. The ore going to the mill, to date, has been taken from development in all parts of the workings, and has averaged 0.92 per cent. MoS_3 , and about 2.7 per cent. iron, with a trace of copper.

Mining System

Two systems of mining are being used. The thin outer edge of the orebody, bounded by the horizontal plane of the tunnel and the steep sloping surface, will be removed by open-pit glory-hole methods during the summer months. For this purpose, drifts have been run about 40 ft. (12 m.) below the surface and parallel to the contours of the hill. From the drifts, raises will be driven to the surface, and the ground will be broken down through them, then drawn into cars, and trammed out to the bins.

Further in, the ground has been laid out in a series of parallel drifts running diagonally across five parallel patented claims—claims are only 150 ft. (45 m.) wide; the drifts are 50 ft. (15 m.) apart and 860 ft. (262 m.) long. From them, stope raises are put up every 30 ft. (9 m.). At a height of 20 ft. (6 m.) above the back of the level, they are widened out to a cone-shaped pocket, at the bottom of which a chute is placed. This widening connects all of the pockets, and, when completed, a stope 400 ft. (121 m.) long and 25 ft. (7.6 m.) wide is ready for shrinkage operations.

While the stope drift is about 860 ft. long, the stope itself is carried up as two separate stopes, each 400 ft. long and 25 ft. wide. In the center, between the stopes, a pillar 40 ft. long is left standing. A two-compartment raise is carried up ahead of the stope through the center of this pillar, and about every 16 to 20 ft., small drift holes are extended from the raise to the stopes on each side. All steel, air lines, etc., are carried up this raise. At the end of each stope, a similar pillar is left, and a one-compartment raise is carried up through it, this also being connected with the stopes by small drifts. By these three raises, the stope becomes readily accessible and good ventilation is obtained. The stopes are to be carried up to the surface as shrinkage stopes, and when the surface is reached, the pillars left between the stopes, both end and side pillars, will be broken down by glory-hole methods into the stopes. In this connection, it must be borne in mind that all of the surface rock within the five claims mentioned is commercial ore.

All of the tunnels have been made large, and 30-lb. rails have been laid in anticipation of long-time operations. At present, a jig-back tramway takes the ore from the tunnel to the crusher bins. A lower tunnel of large size is now being driven, from which a rock raise will be brought up to the working level, and thereafter all haulage will be done through the lower level. A two-compartment raise for men and supplies will also be driven a short distance from the rock raise, which will obviate the present steep climb from quarters to workings.

MILLING PLANT AND PRACTICE

The ore from the mine is dumped into a 300-ton bin, from which it is drawn into the 1-ton buckets of a 700-ft. Leschen jig-back tram. This delivers it to a pair of bins of 400-ton capacity, so designed that both bins feed into the 10 by 20-in. Blake crusher. From the crusher, the ore drops onto a 16-in. (40.6-cm.) conveyor belt, and is elevated into a 400-ton tramway bin. A 4700-ft. (1432.5-m.) Leschen aerial tramway carries the ore from this bin to the mill bin, of 500-ton capacity. From any part of the mill bin the ore can be fed by plunger feeders onto a 16-in. flat conveyor belt, which delivers to a 6 by 6-ft. Allis-Chalmers ball-mill. The ore going to the ball-mill ranges up to 3 in. (76 mm.) in size. From the ball mill, the ore (now crushed to about 20-mesh) goes to a standard duplex Dorr classifier. The overflow goes direct to the flotation machines, while the sands drop to a 6 by 10-ft. Allis-Chalmers ball-mill and return to the same classifier until fine enough for overflow. Crushing is to 120-mesh.

The flotation plant is equipped with five Janney air-mechanical machines, three Callow standard roughing cells, and two Callow half-size cleaner cells. In operation, the feed is proportioned between the Janney and the Callow rougher cells, one machine appearing about as efficient as

the other for roughing purposes. The first four Janney cells deliver rough concentrates to the fifth cell, for partial cleaning; cell No. 4 discharges tails, while the discharge from No. 5 consists of middlings, which are returned to the circuit. The concentrate from the Janney cleaner (No. 5) goes to the first Callow cleaner; the concentrate from this goes to the second Callow cleaner; and recently, in order further to improve the grade, we have converted one of the Callow roughers to a third cleaner. The concentrate from the Callow roughers is finished in the same cleaners as the Janney concentrate. The mill is putting through 300 tons daily, and the four Janneys can treat about that tonnage; the Callows easily treat 100 tons per rougher per day.

The flotation operation is very delicate, as there is nearly three times as much pyrite in the ore as molybdenite, and with a concentration ratio of 115 or 120 to 1, a very large portion of the iron must be dropped, in order to get a concentrate carrying from 65 to 70 per cent. MoS_2 . Another difficulty is that when treating, say, 300 tons of ore per day, carrying 0.92 per cent. MoS_2 , the resulting concentrate, on present recovery, amounts to only 5100 lb. of 65-per cent. product, or only about 4 lb. per minute from the cleaner. We have greatly reduced the size of the cleaner, but it is still difficult properly to control the grade of concentrate. We have, however, averaged 65 per cent. MoS_2 in our product.

A vanner is being installed, to treat the concentrate for the removal of pyrite. Each unit of iron removed will increase the grade of concentrate 2.2 per cent., the concentrate now carrying about 10 per cent. iron. All assays are on a basis of MoS_2 , but the feed to the mill carries from 0.25 to 0.3 per cent. of MoO_3 . In reporting assays, this is figured as MoS_2 , but the oxide is not amenable to flotation. The mill recovery is now 60 per cent. of the total Mo in the feed, which is equivalent to a sulphide recovery of 82 per cent. A great many tests are being made, with encouraging results, for the recovery of the oxide, molybdate. It is interesting to note that the feed to the mill averages almost exactly the figure originally estimated, the recovery being about $11\frac{1}{2}$ lb. of MoS_2 per ton, as against 12-lb. estimated recovery. This recovery will undoubtedly be greatly improved when the process for the recovery of molybdate is installed.

LIVING ACCOMMODATIONS

On Aug. 1, 1917, Climax was a barren waste, with not even a tent. By Feb. 1, 1918, the mill, boiler house, bins and crusher, a 1-mile tramway and an 800-ft. jig-back, had been completed and were in operation.

Although there was a great amount of work to be done in a short time, as much as possible was done for the health and comfort of the men. There is a well equipped hospital of four beds, in charge of a high-class safety-first man, who devotes all of his time to looking after the health of

the men and the sanitary conditions at the camp. Excellent bunk houses have been constructed, steam-heated, with shower baths and modern plumbing. There is also a library. Every effort is made to keep the camp clean and the men healthy and contented, and as a result, there is a good supply of labor.

MARKETING

Until it was demonstrated that an assured supply of molybdenite concentrate could be depended on from Climax, the supply on this continent was variable and, as a result, it was in demand only for chemical manufacture and other limited uses. Much private work had been done in steel laboratories, and some of the advantages of adding molybdenum were known, but the scarcity and uncertainty of supply did not encourage any great expenditure by steel makers in thorough testing of ferromolybdenum. The present output at Climax is about 60 per cent. of the world's output prior to the operations at Climax. The small amount of work done by the steel makers indicated that molybdenum could be used to advantage in combination with vanadium and tungsten, or as a substitute for these metals, giving the steel the same properties at a much reduced cost. At present the market for molybdenum is very limited, and the quoted prices are nominal and do not at all represent the prices at which the material is marketed.

DISCUSSION OF THIS PAPER IS INVITED. It should preferably be presented in person at the Colorado meeting, September, 1918, when an abstract of the paper will be read. If this is impossible, then discussion in writing may be sent to the Editor, American Institute of Mining Engineers, 29 West 39th Street, New York, N. Y., for presentation by the Secretary or other representative of its author. Unless special arrangement is made, the discussion of this paper will close Oct. 1, 1918. Any discussion offered thereafter should preferably be in the form of a new paper.

The Mechanics of Vein Formation

BY STEPHEN TABER,* PH. D., COLUMBIA, S. C.

(Colorado Meeting, September, 1918)

INTRODUCTION

A VEIN may be defined as an aggregation of mineral matter, more or less tabular or lenticular in form, which was deposited from solution and is of later origin than the inclosing rock. This definition differs from the one found in many text-books in that no assumption is made as to the origin of the space occupied by the vein or the manner in which the mineral matter was deposited. In the present paper the writer purposes to discuss the mechanics of vein formation, and does not wish to begin by begging the question.

The origin of ore deposits has been diligently investigated in recent years, but, while much has been written concerning the chemistry of the process, the physical side of the question has received less attention. The source of the ore minerals; the chemical composition of ore-bearing solutions; the relative importance of magmatic and meteoric waters as agents of concentration; and the causes of mineral precipitation have all been discussed at length. On the other hand, little has been written concerning the mechanics of vein formation, and the theories given in text-books today are essentially the same as those developed by the early Cornish and Saxon miners.

Early investigators often regarded both veins and dikes as igneous in origin, but today the theory that vein minerals have been deposited from solutions, either liquid or gaseous, is firmly established. The latter view is supported by the fact that many vein-forming minerals are not found in unaltered igneous rocks; by evidence obtained in the laboratory regarding the solubility of minerals; by the presence of many ore minerals in hot-spring waters; by the occurrence of some veins in regions consisting exclusively of unaltered sedimentary rocks; by evidence as to the temperature at which some minerals are formed; and by the absence of mineral segregation due to difference in specific gravity. There is still, however, much difference of opinion as to whether certain tabular-shaped masses should be classed as veins or as dikes. Some of

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the earlier investigators have also advocated the theory that veins are contemporaneous in origin with the inclosing rock, while others have believed the vein minerals to represent a recrystallization or transformation of the inclosing rock; but these views have now been generally discarded by geologists, and, since they are unsupported by evidence, it is not necessary to discuss them here.

METHODS OF VEIN FORMATION

There are six different ways by which it is conceivable that mineral matter transported in solution may reach its resting place in a vein:

I. It may enter along an open fissure, and be deposited on the walls until the fissure is more or less filled.

II. It may enter along a fracture, bedding plane, or similar passage, and, as it is deposited, force the wall rock apart, thus making room for the growing vein.

III. It may be introduced into an open fissure through small openings in the walls, and thus more or less fill the fissure.

IV. It may be introduced through the walls of a narrow passage or incipient fracture, and, as it is deposited, force the walls apart.

V. It may enter along a fracture or other passage, and replace part or all of the minerals of the wall rock.

VI. It may be derived from the surrounding material and be concentrated by locally replacing part or all of the minerals in the country rock.

Before estimating the relative importance of these methods of vein formation, it is necessary to establish criteria by which the origin of a given vein can be recognized. In studying the larger metalliferous veins having commercial value, it is sometimes difficult to discover evidence bearing on the mechanics of their formation, for only the final results are available for examination, and evidence that probably existed during the early stages of vein formation may have been largely obliterated by replacement or later alterations. The problem is rendered more difficult by the fact that many veins are the result of two or more methods of ore deposition.

In searching for evidence bearing on the mechanics of vein formation, the writer has not confined his attention to the large complex metalliferous veins, but has also made a detailed study of the small and relatively simple veinlets of a region of unaltered sedimentary rocks.¹ Natural deposits of mineral matter found elsewhere than in veins were also examined, and several different types of veins were successfully produced

¹ Stephen Taber: The Origin of Veinlets in the Silurian and Devonian Strata of Central New York. *Journal of Geology* (Jan.-Feb., 1918), 26, 56-73.

in the laboratory, where the origin and development of the more important vein structures could be observed in detail. A discussion of the six ways in which it is possible for veins to be formed, together with such evidence as has been thus far collected, is given below. The present paper is preliminary in nature, and some vein phenomena are not discussed. The investigation is being continued, but it is only through the collaboration of many observers that such problems can be solved.

I

The hypothesis that veins have been deposited from solutions circulating along open fissures until filling was more or less complete is extremely old, and is to be found, in one form or another, in writings on ore deposits from the time of Agricola to the present day. Drusy cavities or vugs, and comb-structure, banding or crustification, are the evidences commonly cited in recent text-books as proof that veins were deposited in open fissures.

Drusy cavities are most common in veins recently formed at shallow depths, and, if we eliminate the openings due to solution in the belt of weathering, they are very rare, or entirely absent in veins formed at great depth. The gold-quartz veins of the Southern Appalachian region are believed to have been formed at depths of three miles or more; and, so far as the writer has been able to ascertain, they contain no vugs. If veins were formed through the filling of open fissures, there is no reason why vugs should not be as common in depth as in higher levels.

The close similarity in structure between drusy cavities and geodes, as emphasized by both Posepny² and Shaler,³ is proof that open fissures are not essential for the development of the former. Shaler observed that in the process of enlargement, which geodes undergo, they sometimes condense and deform the inclosing rock strata. The texture of the vein matter surrounding vugs is often such as to indicate that the crystals lining the cavities have been deposited, as in geodes, from infiltrating solutions rather than from solutions circulating along an open fissure. In many instances the vugs are lined in part with minerals that are secondary in origin.

It has been demonstrated experimentally that pre-existing fissures are not essential for the development of drusy cavities; such openings are commonly present in veins, produced in the laboratory, which have made room for themselves by pushing their walls apart. A careful consideration of all the facts leads to the conclusion that the crystal lining of druses was deposited on the walls of open cavities, and that druses may

² Franz Posepny: The Genesis of Ore Deposits. *Trans.* (1893), **23**, 207, 218, 255.

³ N. S. Shaler: Formation of Dikes and Veins. *Bulletin of the Geological Society of America* (1899), **10**, 260-262.

be formed in veins that were deposited in open fissures, but the mere presence of these druses in a vein does not prove that the vein as a whole was thus deposited.

Werner seems to have been the first to call attention to banding and to explain it as being due to differences in the composition of the solutions from which the minerals were deposited; but Fournet observed that banding was not always parallel to the walls of a vein, since fragments of the adjacent rock were sometimes surrounded by layers of vein minerals, as, for example, in the "ring-ore" of the Hartz.⁴ De la Beche discussed the formation of comb-structure and of vugs or druses, and cited these phenomena as tending to prove that some veins owe their width to repeated reopenings of the fissures.⁵

Posepny, in his treatise on "The Genesis of Ore Deposits," devoted many pages to "the filling of open spaces," and referred to banding or "crustification" as the characteristic feature of cavity-filling; but he acknowledged that the genesis of the non-crustified deposits was more difficult of determination, and concluded that "they were not deposited in pre-existing spaces."⁶

Veins of the latter class are, however, very much more common than those showing crustification. Sometimes banding is very imperfect, and again one part of a vein may show distinct crustification, while in other parts this structure is entirely absent. The crustified portion of some veins "is surrounded by solid quartz possessing no banded or comb-structure."⁷ Banding, as well as vugs, may result from the filling of open fissures; it would then necessarily be symmetrical with respect to the center, but in many veins it is asymmetrical. Banding can be formed in other ways, however, and therefore it can not be regarded as proof of the manner of vein deposition. In veins produced in the laboratory, which were not deposited in open spaces, both symmetrical and asymmetrical banding were obtained by changing the composition of the vein-forming solutions. A banded structure may also result from replacement or from metamorphic processes.

When crystals are slowly enlarged by additions of material from supersaturated solutions, they develop crystal faces on their exposed surfaces; prismatic crystals, such as quartz, are commonly normal to some supporting surface from which they project, and therefore often have a parallel orientation. This is well illustrated by the crystals lining geodes, drusy cavities in veins, and similar openings in rocks; but in vein quartz

⁴ Henry T. De la Beche: *Report on the Geology of Cornwall, Devon, and West Somerset*. London (1839), 370-371.

⁵ *Op. cit.*, 339-342.

⁶ Franz Posepny: *Op. cit.*, 262.

⁷ J. E. Spurr: *Geology of the Tonopah Mining District, Nevada*. *U. S. Geological Survey Professional Paper* No. 42 (1905), 171.

crystal faces are relatively rare or entirely absent except in the immediate vicinity of drusy cavities, and microscopic examination proves that parallel orientation is likewise uncommon in massive quartz. There is unquestionably some recrystallization of vein minerals contemporaneous with their deposition, as a result of which certain crystals may be enlarged at the expense of others, but this would not change the crystallographic orientation. Crystal faces and parallel orientation are most common in veins formed at very shallow depths, and seem to be practically absent from the deeper veins. Veins formed at shallow depths occasionally show a spheriodal texture with prismatic crystals of quartz radiating outward from numerous central nuclei. Vein quartz usually has a granular texture similar to that shown by many igneous rocks, being due to mutual interference of the growing crystals. The tendency to assume a regular polyhedral form is stronger in pyrite than in any of the other minerals commonly present in veins, and yet pyrite crystals seldom show idiomorphic outlines except where they are embedded in older minerals which they have partly replaced.

If veins were formed through deposition of minerals on the walls of open fissures, there should be a suture line near the center of the veins, marked by occasional vugs where filling was incomplete; but most veins show no trace of such a structure; in many of the smaller veins individual crystals extend from wall to wall, and vugs, when present, are not always confined to the central portions of veins. Rickard has described and figured such a cavity which extended for several feet along the foot-wall of the Jumbo vein in the Enterprise mine of Rico, Colorado.⁸

A soft gouge or selvage is often found along one or both walls of a vein, and, if this were present before the deposition of the vein minerals, it could never have remained in place on the walls of an open fissure even while supporting no additional load of vein minerals. Occasionally the gouge matter is found in the center of a vein.

The change in mineral composition when a vein passes from one rock to another has been attributed in several instances to substances present in the wall rock that act as precipitants;⁹ but this action could hardly occur if the vein-forming solutions were separated from the country rock by layers of impermeable mineral matter deposited on the walls of the fissure. Most veins are accompanied by some replacement and mineralization of the wall rock, but there is no evidence that the process of replacement is completed before fissure-filling begins. The mineral composition of some veins varies greatly along their strike; this is

⁸ T. A. Rickard: Vein-walls. *Trans.* (1896), 26, 224-226.

⁹ Richard Beck: *The Nature of Ore Deposits*; Translation by W. H. Weed. New York (1909), 384-395.

W. P. Jenney: The Chemistry of Ore-deposition. *Trans.* (1903), 33, 456-457.

difficult of explanation under the assumption that the minerals were deposited from solutions filling continuous open fissures.

It is inconceivable that large fissures could have remained open at great depth below the surface during the long period of time required for their filling by mineral deposition. As a result of his ingenious experiments, Adams concludes that small cavities may exist in granite to a depth of at least 11 miles, but he distinctly points out that the walls of larger openings would collapse under much less pressure.¹⁰ The latter fact has apparently been overlooked by some geologists. Data obtained from tests on small specimens of stone free from fractures and flaws can not be used in computing the depth at which fissures would be closed by collapse of their walls. In the vicinity of many veins the country rock shows evidence of having been greatly shattered prior to the entrance of vein-forming solutions, for branching veinlets sometimes extend out from the main vein and ramify in all directions. It is especially difficult to understand how open fissures could be maintained in rock that has been shattered to the extent shown by the "horse-tail" structure of veins at Butte¹¹ and in the Basin District,¹² Montana.

The hydrostatic pressure of solutions occupying an open fissure would of course help to support the walls, but, on the other hand, there are factors that would aid in closing them. Deep-seated veins are formed under high-temperature conditions, which, together with the presence of mineralizers, would reduce the differential stress necessary for rock flowage. Veins are often far from vertical, and some are nearly horizontal.

It is only with great difficulty that openings are maintained in some of the deeper mines during the extraction of ores, and yet veins have been formed at very much greater depth than any reached in mining. Most of the deeper mines are practically dry in their lower levels, which indicates that even the smaller openings in rocks are largely confined to relatively shallow depths.

Most veins are found in mountain regions or in other areas that have been subjected to orogenic stresses, where, because of lateral pressure, gaping fissures are least likely to form; veins are relatively rare in regions of epirogenic movements where normal faults and monoclinical folds prevail. Moreover, the ore deposits that do occur in regions of important normal faulting, as, for example, at Clifton, Arizona,¹³

¹⁰ Frank D. Adams: An Experimental Contribution to the Question of the Depth of the Zone of Flow in the Earth's Crust. *Journal of Geology* (1912), 20, 115-117.

¹¹ Reno Sales: Ore Deposits of Butte, Montana. *Trans.* (1913), 46, Fig. 2.

¹² Paul Billingsley and J. A. Grimes: Ore Deposits of the Boulder Batholith of Montana. *Bulletin* No. 124 (April, 1917), 666. [*Trans.* (1918), 58, 309.]

¹³ Waldemar Lindgren: The Copper Deposits of the Clifton-Morenci District, Arizona. *U. S. Geological Survey Professional Paper* No. 43 (1905).

are not, as a rule, found occupying fault fissures. The presence of slickensides and stria on the walls of veins formed along faults are evidence indicative of closed rather than of open fissures.

The walls of many veins contain angular irregularities of such a nature that the opposite walls would fit perfectly into one another. Such veins evidently do not occupy fault fissures, nor can they be explained by any process of replacement. Many veins also split up and finger out into the country rock in such a way as to prove that the spaces were not formed by faulting.

Yawning chasms in any way comparable in magnitude with the many barren and metalliferous veins are not known today at any place on the surface of the earth, and they are less likely to occur at the depths where most veins have formed; there is no reason, therefore, for assuming their existence in the past, for veins are formed in rock strata of all ages. Neither are partly filled fissures to be found, if the veins containing drusy cavities are excepted. Some veins are enormous in size; according to Suess, the Great Pfahl in the Bavarian Forest is somewhat over 150 km. in length and averages 70 to 115 m. in width. He states that this great quartz vein represents the infilling of a long cleft produced by dislocation.¹⁴ When we consider the multitude of veins, barren as well as metalliferous, and the extremely rare occurrence of open fissures of any kind, it is difficult to believe that many veins have been formed through the filling of such openings.

In the Bendigo gold fields of Victoria, Australia, and also in Nova Scotia, large masses of auriferous quartz, known as saddle-reefs, occur in the crests of anticlinal folds, but open spaces, with the exception of solution caverns in limestone, have never been observed in anticlinal folds, although folded rocks in all stages of dissection are found in many parts of the earth. Simple filling of open fissures of tectonic origin does not explain a change in the width of veins on passing from one wall rock to another, such as occurs in the veins of the San Juan Mountains, Colorado.¹⁵

The lenticular form of veins is also evidence opposing the hypothesis of deposition in open fissures. Most veins are more or less lens shaped; this form is often accentuated, and in extreme cases the lenses are bulbous or almost spherical. Some veins alternately swell and pinch; some consist of small separate lenses strung out along the same line of strike and connected by an almost imperceptible seam; others are made up of small and apparently disconnected parallel lenses irregularly distributed along a narrow belt or zone. Sometimes the lenses are remarkably symmetrical

¹⁴ Eduard Suess: *The Face of the Earth*; Translated by H. B. C. and W. J. Solas, 1, 208-209. Oxford (1904).

¹⁵ C. W. Purington: Ore-horizons in the Veins of the San Juan Mountains, Colorado. *Economic Geology* (1906), 1, 129-133.

(Fig. 5); often they are irregular. The lenticular form is usually best developed in veins formed at depth, or where the wall rock is a highly laminated schist, slate, or shale. The walls are usually sharply defined and there is often other evidence that replacement has not been an important factor in the formation of the lenses.

De la Beche¹⁶ showed that the relative displacement of the walls of an irregular fracture could result in the formation of open spaces which thin out where the opposite walls are in contact, and this has frequently been advanced as an explanation of lenticular veins; but no method of faulting can account for the space occupied by apparently disconnected lenses, and, in some instances, there is positive evidence that the walls have been separated without other displacement. Billingsley and Grimes have recently described short lenticular veins in granite which show no evidence of faulting, "such as shearing in the intervening country rock or displacement of intersected dikes of aplite." They attribute the drawing apart of the walls to tension resulting from the cooling and contraction of the granite;¹⁷ but the distribution of the veins is not such as to relieve tensile stresses in all directions in a shrinking mass, many granites show no evidence of lenticular openings either filled or unfilled, and lens-shaped veins are more common in sedimentary and metamorphic rocks than in igneous rocks.

The bedding planes of sedimentary rocks and the folia of schists and slates, where in contact with lenticular veins, are commonly curved to conform with the curvature of the lenses. The later origin of the veins is indicated by the fact that they occasionally transect the rock structure and contain included fragments of the wall rock. Such displacement of structural features antedating the formation of the vein can be explained only on the theory that the walls have been pushed outward by some force acting from within, for the effects of tectonic forces acting parallel to the rock structure could not be limited so as to confine the formation of lenticular openings to a single plane.

Lenticular veins were believed to be igneous intrusives by some of the earlier geologists, but true dikes do not show such extreme forms, and the theory is also open to many other objections previously cited. Graton¹⁸ concluded that the lenticular gold-quartz veins of North and South Carolina were deposited from solutions which were under such great pressure as they ascended toward the surface that they were able to force apart the walls of small fractures and thus form the lenticular openings.

¹⁶ Henry T. De la Beche: *Researches in Theoretical Geology*, 207-208. London (1837).

¹⁷ *Op. cit.*, 309-310.

¹⁸ L. C. Graton: *Reconnaissance of Some Gold and Tin Deposits of the Southern Appalachians*. *U. S. Geological Survey Bulletin* No. 293 (1906), 60.

This explanation was advocated by Lindgren¹⁹ who opposed the theory that the veins were formed through the "force of crystallization." If the enlargement of vein spaces were due to the pressure of fluids, very flat lens- or tabular-shaped openings would be formed, and not a series of thick lenses more or less isolated and disconnected; moreover, the pressure of the fluid would have to be uniformly maintained until the openings were filled, or the walls would collapse. It is obvious that this

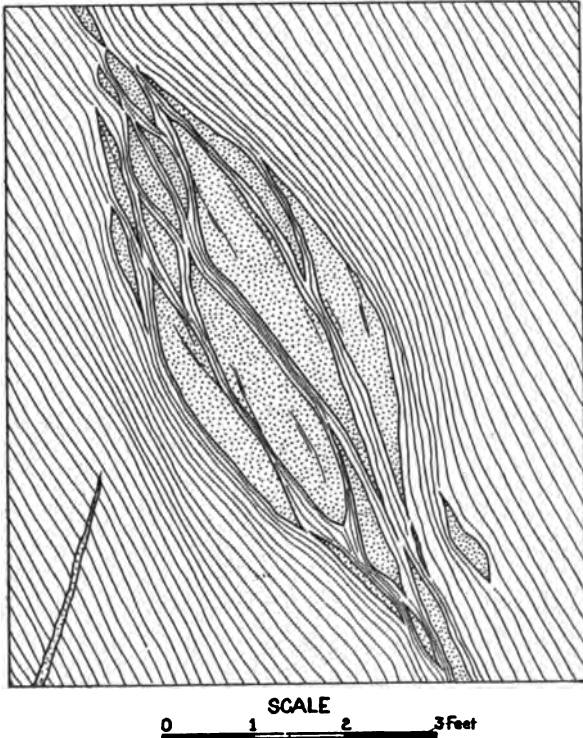


FIG. 1.—QUARTZ VEIN IN SERICITE SCHIST NEAR COLUMBIA, S. C. THE QUARTZ LENS IS SUBDIVIDED BY THIN PARTITIONS OF SCHIST, AND IN PLACES CONTAINS DETACHED INCLUSIONS OF THE WALL ROCK.

theory is inapplicable to many lenticular veins, such as those of calcite or gypsum, formed near the surface in unaltered sedimentary strata. The pressure of fluids cannot account for the formation of lenses that are subdivided by thin partitions of included schist detached from the walls, as illustrated in Fig. 1. In view of all the facts, it must be concluded that the typical lenticular veins were not deposited in preëxisting openings.

The peculiar banded structure, sometimes referred to as "book structure" or "ribbon-ore," resulting from the alternation of narrow

¹⁹ Waldemar Lindgren: The Relation of Ore-deposition to Physical Conditions. *Economic Geology* (1907), 2, 107-108.

veinlets of ore with parallel sheets of slate or schist, is difficult or impossible of explanation under any theory of ore deposition in preëxisting openings. Becker and Day²⁰ have called attention to the fact that in some cases "it can be shown conclusively that the distribution of the slate is not due to faulting." This structure is well developed at many places along the Mother Lode of California, and also in some of the gold and copper veins of the Southern Appalachians. Usually the veinlets, consisting of quartz or calcite, are lenticular in form, and pinch out to be replaced by others a little to one side or farther along the strike; sometimes layers of slate are wholly included within the veins.

The commonest evidence indicating that veins were not entirely deposited in open fissures is furnished by the presence in them of angular inclusions of the country rock. These fragments often show by their shape that they have been detached from an adjacent wall and displaced laterally without falling. Where the inclusions are unaltered by replacement, they could refit perfectly into the positions which they formerly occupied. Inclusions that have suffered alteration are usually more or less rounded or subangular. Posepny states that upon search he always found points of contact between such fragments; but, in many instances, the writer, by making parallel sections, proved that the inclusions were not in contact with the walls or with other fragments.

Inclusions are rare in some veins and plentiful in others, in some cases making up the larger portion of the ore mined. The inclusions also vary in size up to masses so large that it is a question whether they should be classed as "horses" or as country rock inclosed between two branches of a vein. There is no essential difference between some breccia veins and certain ore deposits that consist of a network of anastomosing veinlets which ramify in all directions through the country rock. In veins that are horizontal or dip at flat angles, the inclusions are no more plentiful along the foot-wall than near the hanging wall.

Deposition of mineral matter in opening filters with gas is practically limited to the belt of weathering. Such deposits are, as a rule, easily recognized; they are often finely banded, and usually exhibit stalactitic, mammillary or analogous forms. As they are almost exclusively secondary in origin and obviously of little importance in unaltered veins of primary ores, further discussion is unnecessary here.

The evidence outlined above leads to the conclusion that deposition of mineral matter in widely open fissures is of minor importance in the formation of veins. Minerals deposited in open spaces are present in many veins, especially those formed at shallow depths, though in most cases they make up a relatively small proportion of the total vein mass.

²⁰ G. F. Becker and A. L. Day: The Linear Force of Growing Crystals. *Proceedings of the Washington Academy of Sciences* (1905), 7, 283-284.

Some veins have possibly been formed entirely through the simple filling of open fissures, but they are believed to be extremely rare.

II

The hypothesis that veins may be deposited from solutions entering along extremely small passages and that the growing veins have made room for themselves by forcing apart the inclosing walls has been suggested by investigators from time to time; but it has never received general acceptance, and is practically ignored in text-books treating of the origin of ore deposits. Comparatively little evidence in support of the hypothesis has been published, and the mechanics of the process by which growing crystals exert pressure has not been clearly understood. According to Andréé,²¹ who has compiled an excellent bibliography of the subject, von Weissenbach²² was the first to assume a "force of crystallization" in explaining geologic phenomena. Lavallo,²³ however, appears to have been the first to record experimental proof of pressure exerted during crystal growth.

It has been demonstrated beyond question that growing crystal may exert force and actually grow in directions in which their growth is opposed by adjacent solid bodies, but some geologists²⁴ have doubted that this force is sufficient to separate the walls of veins at great depths. In replying to this objection, attention is called to the fact that *all* crystals have been formed under pressure, and many mineral crystals must have developed under enormous pressure. The effect of pressure or of strain is to increase slightly the solubility of most substances, but the change is very small as compared with that due to difference in temperature. So long as a crystal surface is in contact with a solution supersaturated with respect to that surface, growth will continue no matter how great the pressure or strain may be. The supersaturation of a solution in contact with a growing crystal is maintained by circulation and diffusion through the solution; and, when a crystal grows in a direction in which growth is opposed by an adjacent solid, it is due to the fact that the material necessary for growth is able to diffuse between the crystal and the other solid.

²¹ K. Andréé: Die geologische Bedeutung des Wachstumsdrucks kristallisierender Substanzen. *Geologische Rundschau* (1912), 3, 7-15.

²² C. G. A. von Weissenbach: *Abbildungen merkwürdiger Gangverhältnisse aus dem sächsischen Erzgebirge*, 22, 23, 26. Leipzig (1836).

²³ Jean Lavallo: Recherches sur la Formation Lente des Cristaux à la Température ordinaire. *Comptes Rendus* (1853), 36, 493-495.

²⁴ Waldemar Lindgren: *Op. cit.*, 107.

F. L. Ransome: Discussion sur l'Influence de la Profondeur sur la Nature des Gisements Metallifères. *Congrès Géologique International, Canada* (1913), *Compte Rendu de la XIIe Session*, 305.

The film of solution separating the crystal from the other solid is not expelled by the pressure developed; otherwise, growth would cease. If two perfectly smooth parallel surfaces were separated by a thin layer of liquid which wets them both, capillarity would tend to bring the two surfaces close together, and reduce the thickness of the separating film to a minimum; but it is improbable that this film could be completely expelled by capillarity or even by external force that does not rupture the solids. When a crystal, in growing, approaches another solid, the surfaces that are closest together tend to become parallel, because deposition is most rapid where diffusion is least restricted.

There is abundant evidence that solutions, especially when under great pressure and high temperature, can penetrate even the densest rocks. Penetration takes place between the mineral crystals and along cleavages and microscopic fractures in the minerals themselves. It has been suggested that diffusion may take place directly through individual crystals, but this is doubtful, and certainly has not been proved. Evidence of the enormous quantities of mineral matter which may diffuse for considerable distances through small capillary and sub-capillary spaces is furnished by the size of replacement deposits. The presence of ore minerals having idiomorphic surfaces, where in contact with older minerals which they have partly replaced, proves that in such instances the solution and removal of the replaced minerals has resulted from the growth of the ore minerals, and therefore did not precede the precipitation of the latter so as to form open spaces for their reception.

The pressure effects accompanying the growth of some crystals are evidently, in part at least, due to the tendency to develop crystal faces, but this "linear force of growing crystals" is believed by the writer to be of minor importance. In previous papers²⁵ he has expressed his belief that these pressure effects are to be attributed chiefly to the molecular forces associated with the separation of solids from solution. Laboratory experiments prove that the pressure effects are independent of the cause of precipitation; for they have been obtained where precipitation was induced by cooling, by evaporation, by reactions between liquids, by reactions between liquids and solids, and by reactions between gases and solids. When a single molecule of the solid passes by diffusion into the thin film of solution separating a growing crystal from a foreign body, and attaches itself to the surface of the crystal, a slight displacement of the entire crystal relative to the foreign body results. According to this conception, the mechanism of the process is somewhat analogous to that of a hydraulic jack. It is inconceivable that the addition of a single molecule could displace the crystal in any other way, and there is no

²⁵ Stephen Taber: Pressure Phenomena Accompanying the Growth of Crystals. *Proceedings of the National Academy of Sciences* (1917), 3, 297-302.

evidence of periodicity in the growth of most crystals. The diffusion of a solid through a solution is ascribed to osmotic pressure, and its separation therefrom to the relation between osmotic pressure and solution pressure. The writer thinks it preferable not to use the term "force of crystallization" until it has been definitely established that the pressure effects accompanying the separation of solids from solution are limited exclusively to crystalline solids. There is some evidence that the deposition of non-crystalline substances, such as limonite, may also result in the development of pressure under favorable conditions. This question is now being investigated experimentally, but as yet with only negative results.

Lindgren²⁶ thinks that a platy or schistose structure due to development under one-sided pressure would necessarily characterize veins which have made room for themselves by forcing their walls apart, and that the absence of this structure is evidence indicating that the veins were not so formed. There is, however, much evidence opposing this view. A crystal developing at depth below the surface, completely surrounded by interlocking minerals, is probably under nearly uniform pressure in all directions. Pseudophenocrysts of biotite which have developed in highly schistose rocks under mass static conditions do not show parallel orientation, although in growing they have forced apart the folia of the schist.²⁷ Calcareous concretions which develop in shales and push apart the bedding planes, as shown in Fig. 4, may be even-granular in texture. The writer has examined, microscopically, thin sections cut normal to the surface of these concretions and others cut parallel to the surface without observing any difference in the appearance of the calcite grains. In some concretions that are relatively free from impurities the calcite crystals are elongated normal to the surface.²⁸

Even in cases where growing crystals are subjected to much greater pressure in one direction than in others, they are not necessarily flattened normal to the direction of greatest pressure, for the shape of crystals is often determined by the relative accessibility, in different directions, of the material for growth. This has been proved experimentally by growing slender columnar, and even fibrous, crystals which were elongated in the direction of greatest pressure.²⁹

²⁶ Waldemar Lindgren: Discussion sur l'Influence de la Profondeur sur la Nature des Gisements Metallifères, *Congrès Géologique International, Canada* (1913), *Compte Rendu de la XIIe Session*, 305; and *Mineral Deposits*, 155. New York (1913).

²⁷ Stephen Taber: Geology of the Gold Belt in the James River Basin, Virginia. *Virginia Geological Survey, Bulletin No. 7* (1913), 29-33.

²⁸ R. A. Daly: The Calcareous Concretions of Kettle Point, Lamberton County, Ontario. *Journal of Geology* (1900), 8, 138.

²⁹ Stephen Taber: The Growth of Crystals Under External Pressure. *American Journal of Science*, Ser. 4 (1916), 41, 546, 552.

In laboratory experiments conducted during the last four years, the writer has been successful in growing veins which have made room for themselves by pushing apart their walls; and in these veins such structures as drusy cavities and banding have been obtained. The drusy cavities were due to a local deficiency of the material for vein growth, resulting either from insufficient concentration or from relative inaccessibility; and evidence has been elsewhere cited in support of the hypothesis that at least some of the drusy cavities occurring in mineral veins are similar in origin.³⁰

Banding was produced in laboratory veins by merely changing the composition of the solutions during the growth of the veins. Mineral veins showing asymmetrical banding could have been formed in open fissures only through successive reopenings of the fissure, and usually there is no evidence supporting such an assumption. Asymmetrical banding, as demonstrated by laboratory experiments, may develop in growing veins that make room for themselves whenever the circulation of the vein-forming solutions is limited to a single wall. There is much evidence indicating that the banding found in metalliferous veins is often due to deposition from solutions circulating along the walls of the growing veins, and that the minerals deposited last are sometimes concentrated near the walls rather than in the center of the veins, as would be necessary on the assumption of ore deposition in open fissures.

Many large veins show a regular arrangement of quartz in the center and chalcedony near the walls. On the assumption that such veins are referable to the activity of hot-spring waters, Beyschlag, Vogt and Krusch³¹ attribute this regular arrangement to the cooling effect of the walls on the ore-bearing solutions, for, as is well known, quartz usually separates from solutions at a higher temperature than chalcedony. It is just as logical, however, to assume that the vein-forming solutions gradually became cooler because of the slow cooling of the igneous rocks from which the heat was derived.

The expiring stages of igneous activity are often marked by the formation of veins through deposition from hot ascending solutions, and in such veins the commonest gangue minerals are quartz and calcite. Similar deposits are formed about hot springs where the waters reach the surface. Calcite is usually deposited later than quartz, but in some instances this order is reversed, and then there is more or less replacement of calcite by quartz. According to Spurr,³² the calcite veins of Ararat

³⁰ Stephen Taber: The Origin of Veinlets in the Silurian and Devonian Strata of Central New York. *Journal of Geology* (1918), 26, 63, 65.

³¹ F. Beyschlag, J. H. L. Vogt and P. Krusch: *The Deposits of the Useful Minerals and Rocks*; Translated by S. J. Truscott. 1, 104-105. London (1914).

³² J. E. Spurr: Geology of the Tonopah Mining District, Nevada. *U. S. Geological Survey, Professional Paper No. 42* (1905), 101-104.

Mountain in the Tonopah District are in places beautifully banded, with quartz in the center and carbonates near the walls. These veins are locally as much as 20 ft. thick, but are exceedingly irregular and non-persistent. The rhyolite forming the walls is in places silicified by the vein-forming solutions, but there is no mention of replacement of calcite, and in many cases the carbonates were observed occupying cavities in the silicified rhyolite, thus indicating a later deposition for the carbonates. Spurr states that "these are fine examples of veins which have filled open fissures," but the facts cited above would indicate that the veins had made room for themselves by forcing their walls apart, and this hypothesis is also supported by the presence of numerous angular rhyolite fragments within the veins.

Small roughly banded veins with calcite in the center and later pyrite along the walls have been described by the present writer. The pyrite is partly in the form of idiomorphic crystals which replace both the earlier vein calcite and the wall rock.³³

An irregular and more or less interrupted banding, as in specimens of ore from Silverton, Colorado, is much more common in veins than an evenly banded structure such as is usually found in travertine, agate, and other deposits known to have been formed in open spaces. Very imperfect banding or absence of banding may result when mineral deposition, instead of being confined to the walls, takes place partly or entirely within the growing vein, the later minerals making room for themselves by replacing or mechanically displacing the earlier minerals. The later minerals may be localized, through deposition along well-defined channels of circulation, or they may be deposited throughout the vein mass. Where the latter occurs, the material for vein growth must be supplied, at least partly, by diffusion between the earlier minerals. There is much evidence that this method of mineral deposition is of the utmost importance in the formation of ore deposits.

Many veins are intersected by numerous small but well-defined veinlets, consisting chiefly of the later minerals, though often the growth of these veinlets has been practically contemporaneous with the formation of the vein as a whole. Minute veinlets are often revealed by microscopic examination of ore when their presence would not be suspected from a megascopic examination. These microscopic veinlets frequently cut directly through the older minerals, and separate the fragments without other displacement. Occasionally the veinlets may be traced considerable distances, but usually they are non-persistent, and often they are confined to the limits of a single crystalline individual. When thus limited, the veinlets sometimes follow crystallographic directions in the older minerals.

³³ Stephen Taber: *Op. cit.*, 65-66.

The deposition of mineral matter within a growing vein is not, however, limited to intersecting veinlets, and there is also evidence of more or less contemporaneous recrystallization of some minerals during the enlargement of veins. When very small veinlets are examined microscopically, it may be observed that the individual mineral crystals, usually extending from wall to wall, tend to vary in size with any variation in the thickness of the veinlets. This can be explained only on the assumption that the enlargement of the veinlets has been accompanied by an enlargement of some of the vein minerals and the elimination of others. In other words, the crystals which are less stable because of smaller size, or

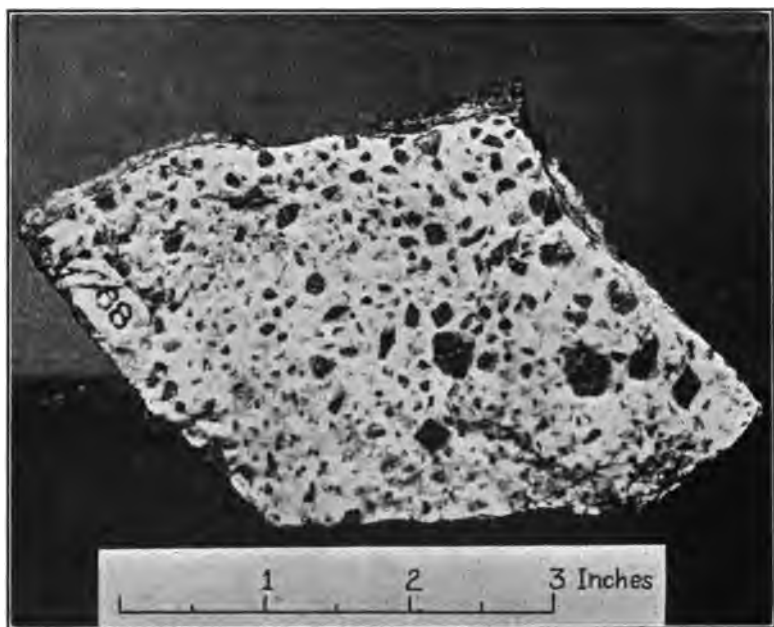


FIG. 2.—VEIN SPECIMEN FROM THE SWAUK DISTRICT, WASHINGTON, SHOWING INCLUSIONS OF WALL ROCK IN A MATRIX OF QUARTZ.

unfavorable orientation or location, tend to redissolve, and thus furnish additional material for the growth of their more fortunate neighbors.

Evidence of mineral deposition within growing veins is furnished by the separation of included fragments of the country rock from one another as well as from the walls. In such cases the fragments often show by their shape that they would fit perfectly together. Inclusions are occasionally found in most veins formed by simple deposition unaccompanied by appreciable replacement, and in some veins the inclusions make up a large percentage of the vein mass. Where the inclusions are abundant, they are sometimes rather uniformly distributed (Fig. 2), as in the so-called "bird's-eye" quartz found in gold

veins of the Swauk district of central Washington. The angular inclusions are of black shale, much silicified, while the matrix is of quartz and calcite. The quartz is partly in the form of small prisms which radiate outward from the separated fragments. At their ends some of these prisms mutually interfere with those radiating from neighboring inclusions, while others project into drusy cavities. According to Smith,³⁴ the wall rock is in places much shattered, with many small quartz veins traversing it in all directions, so that it is difficult to draw any limits to the vein itself, and there is a transition from this shattered wall rock into the typical "bird's-eye" quartz. Russell described these veins, and suggested that the vein minerals "in crystallizing have exerted a force analogous to the expansion of water in freezing, which crowded the rock fragments asunder."³⁵

Von Cotta discussed breccia structure in veins, and stated that in some cases it seems to be due to a special force of crystallization of the principal vein mass, while in others it is to be explained by the opening of vein fissures more than once.³⁶ The latter explanation, however, is obviously inapplicable to such veins as those described above in which the spherulitic texture is well developed with quartz prisms radiating in all directions from the nucleal fragments. In some veins having a spherulitic texture the nuclei of the spheroids consist of earlier vein minerals instead of fragments of the country rock. This is well illustrated by some of the veins in the Telluride³⁷ and Silverton³⁸ districts. Less frequently the nuclei are surrounded by several layers or concentric shells differing in mineral composition. This texture, variously known as "cockade ore," "ring ore" and "concentric ore," was described by von Weissenbach as early as 1836. He noted that there was no contact between the original fragments, and attributed their separation to the crystallizing force of the later minerals.³⁹ The spherulitic textures seem to be limited to veins formed at comparatively shallow depths.

The laboratory veins, which made room for themselves by forcing their walls apart, were sometimes branching, and frequently contained

³⁴ George Otis Smith: *Gold Mining in Central Washington. U. S. Geological Survey, Bulletin No. 213 (1903), 79.*

³⁵ I. C. Russell: *A Preliminary Report on the Geology of the Cascade Mountains in Northern Washington. U. S. Geological Survey, 20th Annual Report, Pt. II (1900), 207.*

³⁶ B. von Cotta: *Die Lehre von den Erzlagern, 25. Freiberg (1855).*

³⁷ C. W. Purington: *Preliminary Report on the Mining Industries of the Telluride Quadrangle, Colorado. U. S. Geological Survey, 18th Annual Report, Pt. III (1897), 798-799.*

³⁸ F. L. Ransome: *A Report on the Economic Geology of the Silverton Quadrangle, Colorado. U. S. Geological Survey, Bulletin No. 182 (1901), 91-92.*

³⁹ C. G. A. von Weissenbach: *Abbildungen merkwürdiger Gangverhältnisse aus dem sächsischen Erzgebirge, 22. Leipzig (1836).*

inclusions of the wall material—a structure which could not be duplicated experimentally by any method of vein deposition in open spaces.

In a manner similar to that described above, certain vein minerals of early deposition are commonly ruptured, and the fragments separated by the growth of later minerals. This is well illustrated by many tourmaline crystals found in quartz veins, and also by pyrite and other sulphide minerals present in ore deposits. Pyrite is usually one of the first sulphide minerals deposited, and microscopic examination shows that the pyrite crystals are commonly ruptured and the fragments separated by later minerals, such as chalcopyrite, bornite, etc. Graton and Murdoch, after an extensive investigation, state that

"this is the characteristic structure of the average primary copper ore. . . . In such ores there can be no doubt that the pyrite has undergone actual mechanical deformation, for in some instances it is found that somewhat separated fragments would fit perfectly together, even to the minor irregularities, and would collectively form a compact grain if the intervening cement were removed. Such an occurrence gives the appearance of an exploding bomb. The cause of this crushing and distortion is not yet clear, but it is plain that it took place in an early stage of crystallization of the ore, because no trace of such a thing is commonly to be found in the later sulphides or in the gangue, in the latter of which it would be expected that crushing or at least strain-shadows would be seen in thin sections if these materials had been subjected to stress."⁴⁰

Emmons⁴¹ discussed this structure of sulphide ore deposits, and attributed it to regional metamorphism, but it is also a peculiarity of deposits found in non-metamorphic areas, and this peculiar structure is not characteristic of any type of metamorphic rock. The ore deposits described by Emmons are, it is true, situated in a belt of intensely dynamo-metamorphosed rocks, but the orebodies, while roughly lenticular in form and elongated parallel to the rock structure, are very wide in comparison with their length. Emmons, in commenting on this fact, states that "as a class they seem to be wider than deposits not metamorphosed. This is just the opposite of what should be expected, for, from internal evidence, one gets the impression that they have been squeezed thin."⁴²

The separation of fragments of pyrite and other early minerals is evidently due to the growth of the later minerals, but the manner in which the fractures were first formed is not always clear. In some cases the fracturing of crystals appears to have resulted from external pressure, often due to the growth of later minerals, and in other cases it is probably caused by the development of later crystals in the small cavities present in most crystals or along planes of incipient cleavage or parting. The

⁴⁰ L. C. Graton and Joseph Murdoch: *The Sulphide Ores of Copper. Some Results of Microscopic Study. Trans.* (1913), 45, 37.

⁴¹ W. H. Emmons: *Some Regionally Metamorphosed Ore Deposits and the So-called Segregated Veins. Economic Geology* (1909), 4, 755-781.

⁴² *Op. cit.*, 777.

latter view is supported by the presence in some crystals of dots and stringers of the later minerals arranged chiefly in parallel lines along crystallographic directions.

While some minerals found in veins are commonly fractured and the fragments separated, this structure appears to be rare in other minerals, such as galena, having equal or greater porosity and cleavability. This difference can not always be attributed to later crystallization. In some cases it is possibly due to a difference in the surface tension existing between different minerals and the ore-bearing solutions, but no definite conclusion can be drawn until more data are at hand.

Minerals of early crystallization are occasionally bent as well as fractured, and then the evidence of deformation by external forces is conclusive. Emerson⁴³ has described large crystals of spodumene apparently bent, and in some cases broken, by the growth of later minerals, for the vein in which they occur is not crushed or sheared. The forces that bent the large spodumene crystals through angles of 45° and 90° without fracturing must have been applied gradually through a considerable period of time while the crystals were imbedded in a matrix of other minerals. Bent and broken crystals of covellite, the intervening spaces being filled with "later, but nevertheless primary, bornite," have been described by Graton and Murdoch.⁴⁴ The flakes of mica and chlorite found in some veins are often bent and shredded by the growth of sulphides.

The hypothesis that veins have made room for themselves by forcing their walls apart furnishes a ready explanation of lenticular form and of "book structure" or "ribbon ore," features characteristic of veins formed in highly laminated rocks, and these features are difficult or impossible of explanation under any other theory of vein formation. According to this view, "book structure" has resulted where the ore-bearing solutions have entered along closely spaced parallel planes, and deposited mineral matter in the form of veinlets, which, in growing, have gradually separated the laminae of the country rock. Becker and Day⁴⁵ were the first to suggest this origin for the so-called "ribbon-ore" of the Mother Lode district in California. The separation of the silicified shale fragments in the ore breccia forming the Enterprise blanket of the Rico district, Colorado, should probably be attributed to a similar process. Ransome has reproduced a photograph of a beautiful specimen of this breccia from the Newman Hill mine.⁴⁶

⁴³ B. K. Emerson: *Geology of Massachusetts and Rhode Island. U. S. Geological Survey, Bulletin No. 597* (1917), 257.

⁴⁴ L. C. Graton and Joseph Murdoch: *Op. cit.*, 51.

⁴⁵ G. F. Becker and A. L. Day: *Op. cit.*, 284.

⁴⁶ F. L. Ransome: *The Ore Deposits of the Rico Mountains, Colorado. U. S. Geological Survey, 22nd Annual Report, Pt. 2, 279, and plate XXXV.*

Dunn states that the saddle-reefs and leg-reefs of the Bendigo district, Australia, are often laminated by the inclusion of thin films of slate and occasionally of "thick substantial flakes." The laminations are farther apart where the reefs are widest, and closest together where the reefs are narrowest. The laminations are also more closely spaced near the walls. Dunn cites these facts as evidence that the quartz has forcibly made room for its accumulation, and concludes that the growth of the quartz layers was continuous during the period of reef formation.⁴⁷

Lenticular form is characteristic of most aggregations of mineral matter that develop in highly laminated rocks, such as shales or schists, and displace rather than replace the older minerals. Eye-like lenses may result from the growth of a single crystal, in which case the outer cir-

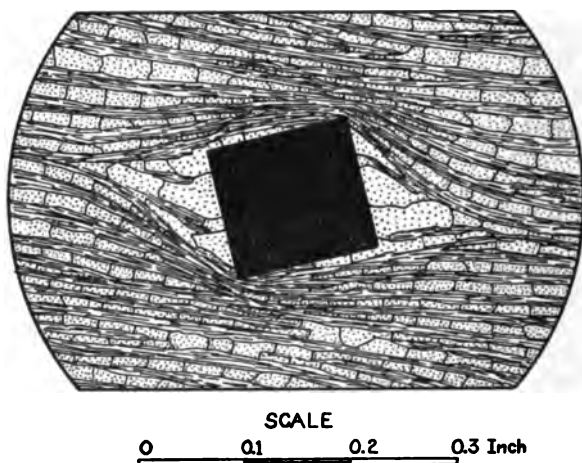


FIG. 3.—SKETCH SHOWING EYE-LIKE LENS IN QUARTZ MICA SCHIST. THE LAYERS OF MICA HAVE BEEN DISPLACED BY THE GROWTH OF THE PYRITE CRYSTAL WHILE QUARTZ HAS BEEN LARGELY REMOVED FROM POINTS OF GREATEST PRESSURE AND RE-DEPOSITED WHERE THE PRESSURE WAS LEAST.

cumference of the lenses is filled in with other minerals, as in Fig. 3. The single crystal may be of such mineral as garnet, biotite, pyrite, galena, or sphalerite, while the remainder of the lens is filled with quartz or calcite. Larger lenses are formed by the growth of crystalline aggregates. The calcareous concretions shown in Fig. 4 are essentially similar to the gold-quartz lenses shown in Fig. 5, and in both cases the form has obviously resulted from similar processes. In a previous publication,⁴⁸ the writer has cited the lenticular form of certain auriferous-quartz veins as evidence

⁴⁷ E. J. Dunn: Reports on the Bendigo Gold-field Nos. 1 and II. *Victoria Department of Mines* (1896), 24, 25, 27.

⁴⁸ Stephen Taber: *Geology of the Gold Belt in the James River Basin, Virginia. Virginia Geological Survey, Bulletin No. 7* (1913), 222-231.

that the vein minerals had made room for themselves by forcing the walls apart. One of these veins, exposed in the Tellurium mine, Virginia, consisted of lenses which were in some cases wonderfully symmetrical in form. In laboratory experiments, lenticular veins were obtained through the slow growth of crystalline masses of salts between layers of heavy cardboard coated with paraffine.

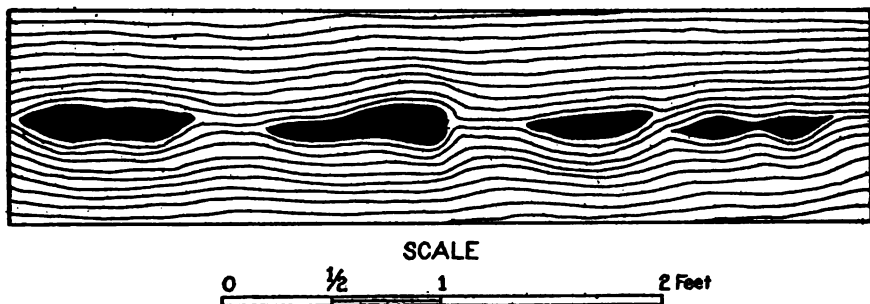


FIG. 4.—CALCAREOUS CONCRETIONS IN SHALE, NEAR UNION SPRINGS, N. Y.

According to this hypothesis, the veins have been deposited from solutions which have penetrated slowly along lines of least resistance, such as faults, fractured zones, planes of bedding or schistosity, or through porous strata; where appreciable openings existed, these have been filled, but the

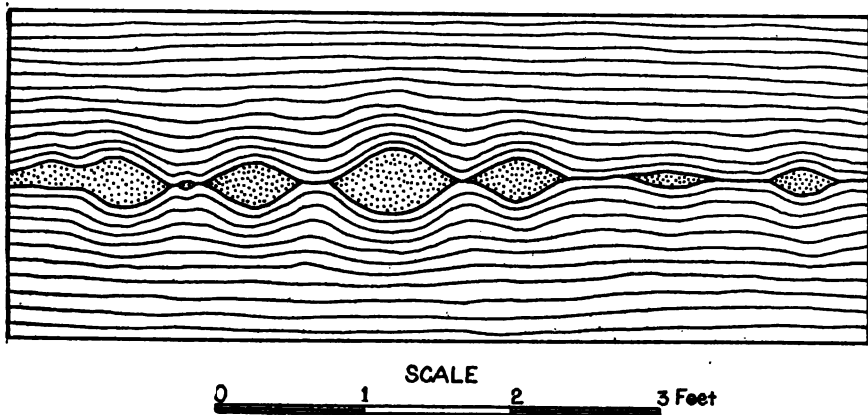


FIG. 5.—SYMMETRICAL LENSES OF A GOLD-QUARTZ VEIN EXPOSED IN THE TELLURIUM MINE, VIRGINIA.

veins have chiefly made room for themselves by forcing apart the inclosing country rock. The form assumed by the growing deposits is determined by the nature of the opening along which the solutions enter, by the accessibility of the ore-bearing solutions during the growth of the ore-body, and by the forces resisting enlargement. When the material for growth is everywhere equally available, the shape produced is that which

requires the least expenditure of energy. This furnishes an explanation of the swelling of some veins where they pass into less rigid rocks, and of the growth of "saddle-reefs" in the crests of anticlinal folds where the rigidity of arching strata relieves the underlying beds of part of their load.

After carefully considering all the facts, there seems to be no escape from the conclusion that it is possible for growing veins to make room for themselves by forcing their walls apart; and the evidence indicates that many veins have been formed in this manner.

III

That veins have been formed of material leached from the inclosing rock, transported in solution and introduced into open fissures through their walls is the old lateral-secretion hypothesis advocated by Bischof, Sandberger, and others. It was vigorously opposed by Posepny, and has been abandoned, in its original form at least, by practically all geologists. Much evidence against the hypothesis has been recorded by others and need not be repeated here. It is also open to the same objections as all hypotheses postulating gapping fissures as a prerequisite for the formation of veins.

In its narrower form this hypothesis confines the derivation of the vein minerals to the wall rock in immediate contact with the deposits, and, therefore, is especially applicable to such veins as the calcite veins in limestone and calcareous shales, gypsum veins in gypsiferous strata, quartz veins in siliceous rocks, and chrysotile veins in serpentine. The veins belonging to this class are commonly horizontal or nearly so, and frequently ramify in all directions through the country rock so as to make up a large proportion of the total mass; hence the difficulty of explaining the formation and maintenance of open fissures is even greater for such veins than for others.

Laboratory investigations indicate that two different types of deposits may be formed in open spaces when mineral matter is introduced through small openings in the walls. One type is formed when mineral matter is deposited from solutions subsequent to their entrance into cavities, in which case the deposits are similar to those formed in open spaces by circulating solutions. The minerals deposited on the inside of geodes, and also in many of the drusy cavities of veins, have evidently been deposited in this way, though there is no evidence that large veins have had such an origin. In the belt of weathering, the deposits usually show stalactitic or analogous forms.

The other type is due to the deposition of mineral matter from super-saturated solutions which do not enter the cavities. In this case additions are made to growing crystals only at their bases, where they are attached to the walls, thus making them columnar, acicular, or fibrous. Because of inequalities in the supply of material, the resulting fibers are unequal in length and in places entirely absent. Where the fibers are in close con-

tact with one another, they are usually parallel and normal to the surface from which they grow; where the fibers are isolated or in small groups, they are commonly curved, and sometimes form tangled coils. Thin crusts are often formed on the walls and later pushed outward by the growing crystals, which also occasionally detach fragments of the wall-material and displace them in a similar manner. Mineral deposits of this type may sometimes be seen forming on the walls of caverns and in other favorable places. Vugs and smaller openings found in veins often contain minerals, usually secondary in origin, which exhibit this structure; but there is no evidence of vein fissures having been filled with such deposits. The filiform varieties of the native metals have probably developed in this way, and some intermediate forms may be due to a modification of wire-like varieties by solutions which have occupied the cavities.

IV

That the material for vein formation has been supplied through small, closely spaced openings in the walls, as the growing veins have made room for themselves by forcing their walls apart, is the hypothesis advocated by the present writer, in previous papers,⁴⁹ as offering an explanation of cross-fiber veins. Most of the evidence supporting this view has been published, and therefore it need not be discussed in detail here.

A somewhat similar explanation of the origin of certain fibrous veins was suggested by von Weissenbach in 1850, but this was not known to the writer until after the publication of the papers referred to above. Von Weissenbach⁵⁰ described the growth of fibrous gypsum crystals on the walls of old buildings and of the needle ice that forms on clayey soils, comparing it with the formation of the fibrous veins. He thought that vein walls of soft material might be pushed back, or that the growth of the needle-like crystals was simultaneous with the widening of the vein fissures which resulted from shrinkage due to drying. As evidence in support of this hypothesis, he states that fibrous veins are never persistent and never show banding or drusy cavities; but this statement is not altogether true, for color banding parallel to the walls is sometimes present in veins of fibrous celestite, and drusy cavities have been observed in similar veins of calcite and of gypsum.

Cross-fiber veins are composed essentially of a single mineral, which is also usually an important constituent and often the dominant mineral in the wall rock. For example, there are fibrous veins of quartz in sandstone, of calcite in limestone, and of chrysotile in serpentine. In

⁴⁹ Stephen Taber: *The Genesis of Asbestos and Asbestiform Minerals. Trans.* (1917), 57, 71-84.

The Origin of Veinlets in the Silurian and Devonian Strata of Central New York. Journal of Geology (1918), 26, 61-65.

⁵⁰ C. G. A. von Weissenbach: *Über Gangformation envorzugsweise Sachsens; Cotta's Gangstudien*, 1, 66. Freiberg (1850).

rare instances the vein mineral is not found in the wall rock, but in such cases it is a secondary mineral which has evidently been derived from minerals that are present in the wall rock. Veins of fibrous chalcantite an inch in thickness have been found in the Yavapai mine at Morenci, Arizona.

All cross-fiber veins, irrespective of mineral composition and kind of wall rock, are characterized by the same structural peculiarities. The mineral fibers are parallel to one another, and in many instances there is direct evidence that they extend in the direction in which the walls have been displaced during the process of separation. In most veins the fibers are approximately normal to the walls, but frequently they are oblique, and, if the course of the vein is not straight, the fibers may be normal to the walls at one place and oblique at another. This is well illustrated in specimens from Hoboken, New Jersey, showing nemalite veins in serpentine. The fibers are usually straight, especially when the veins are small, parallel, and not very numerous; often they are curved or abruptly bent, and this may be observed most frequently where the veins branch, intersect, and ramify in all directions. Sometimes there are several bends in the fibers, thus giving the veins a banded appearance due to unequal reflection of light where the fibers run in different directions, and ordinarily this pseudo-banding is symmetrical with respect to the central portion of the veins. A central parting is present in some veins, several partings are present in others, and in many veins the fibers extend from wall to wall without a break. The partings are often very irregular, appearing as though displaced parallel to the fibers, and similar irregularities may occasionally be noted in the bands that run parallel to the vein walls. Angular inclusions are common, especially along lines of parting, and in many instances it is evident that these fragments have been merely detached from the adjacent walls and displaced laterally. Fibrous veins as a class are non-persistent, and usually have a marked lenticular form.

The structural features here given are common to all kinds of cross-fiber veins; and, with the exception of lenticular form, all of these features have been duplicated in veins grown in the laboratory. All of the features may be satisfactorily explained under the hypothesis outlined above, while many of them are inexplicable under any other hypothesis so far advanced.

The formation of veins through lateral secretion is not necessarily confined to the zone of vadose circulation, as argued by Posepny⁵¹ and Raymond,⁵² for it has been proved that the vein minerals may be trans-

⁵¹ Franz Posepny: *The Genesis of Ore-deposits—Discussion*. *Trans.* (1894), 24, 967.

⁵² R. W. Raymond: *Idem*, 985-986.

ported to the walls of the growing vein by diffusion through solutions occupying minute spaces, instead of by circulation.

The fibrous structure has been attributed by the writer to a mechanical limitation of crystal growth through the addition of new material in only one direction. In veins of the asbestiform minerals, the fibrous structure is accentuated by a normal prismatic habit and cleavage. In studying cross-fiber veins of calcite and of gypsum, it was found that the diameter of the fibers varied with the spacing of the openings through which the material for growth was supplied, and that the veins were non-fibrous where they passed through relatively impervious chert nodules which forced the vein-forming material to diffuse between the walls. Therefore, if material reached a growing vein through openings in the walls, spaced sufficiently far apart, it would be impossible to determine from the structure whether the vein had been formed through a process of lateral secretion or not. A gradation is, therefore, possible from fibrous veins to non-fibrous veins of class II. The fibrous structure of some veins may be made coarser or even completely obliterated as a result of recrystallization, since, for many minerals, a fibrous form is not the most stable.

It has been suggested elsewhere that minimum resistance to growth may often be the factor which has determined the location of chrysotile veins in serpentine, and there is considerable evidence that cross-fiber veins in general tend to develop in those places where the least expenditure of energy is required in making room for them. The cross-fiber veins in stratified rocks are commonly parallel to the bedding, especially where the beds have not been greatly disturbed; and in folded strata the veins in places may be largely confined to the crests of anticlines. These facts are well illustrated by the crocidolite veins of West Griqualand, South Africa, which are briefly described below. For this description⁵³ the writer is indebted to Dr. A. W. Rogers, Acting Director of the Geological Survey of the Union of South Africa.

The cross-fiber crocidolite is interbedded with cherty and magnetite layers, as a rule, but it breaks across these beds where the latter are bent and broken, though the amount of cross-fiber mineral obtained from these cross-fractures or veins is quite insignificant. Where the beds are sharply folded the cross-fiber mineral thickens very much in the arches and troughs, and it may disappear completely in the connecting limbs. The folding and fracturing of the beds was completed before the crocidolite assumed the cross-fiber form; I have not seen the fiber disturbed by these processes, and it appears that its formation took place very soon after, or during, the time when the beds were disturbed. Minute fibers of crocidolite are distributed, more or less abundantly, through the sedimentary beds lying between the layers of cross-fiber mineral.

⁵³ Written communication, dated Mar. 5, 1917.

V

The formation of veins through replacement of country rock by ore minerals, introduced in solution through small cracks, was suggested by Charpentier as early as 1778.⁵⁴ Little evidence in favor of the hypothesis could be cited at that time, and therefore it received almost no attention for nearly a century. Facts learned from the study of pseudomorphs were gradually applied to the formation of ore deposits, and, as evidence accumulated, it became evident that metasomatism or replacement is an important factor in the formation of ore deposits. In 1910 Lindgren published his essay, "Metasomatic Processes in Fissure Veins,"⁵⁵ in which he described in detail the various changes that take place in wall rock as a result of vein formation, and suggested a classification of veins based on characteristic metasomatic processes. It is now generally recognized that while the wall rock of many veins shows absolutely no evidence of metasomatism, most of the larger metalliferous veins, on the other hand, are bordered by altered zones, varying in width and intensity of alteration, and some veins have been formed almost entirely through processes of replacement.

Criteria for the recognition of replacement have been given by Lindgren,⁵⁶ Irving,⁵⁷ and others, and therefore a discussion of this phase of the subject may be omitted here. In regard to the mechanics of replacement, the views of the present writer are slightly at variance with those of the authorities just cited, and it is this question that is discussed in succeeding pages.

The changes which take place in wall rocks as a result of vein-forming processes are often complex, for most rocks are composed of several minerals differing in chemical composition and physical properties, while the ore-bearing solutions may also contain many constituents. The problem can be simplified somewhat, however, by considering separately the various ways by which changes may take place in each individual mineral of which the rock is composed.

One mineral may take the place of another in at least three different ways: (1) by solution of the original mineral and subsequent deposition in the space vacated; (2) by solution of the original mineral and simultaneous deposition of the replacing mineral without chemical reaction between them; (3) by a chemical reaction involving the addition, subtraction, or interchange of one or more elements.

(1) While minerals are sometimes deposited in spaces of dissolution,

⁵⁴ S. F. Emmons: Theories of Ore Deposition Historically Considered. *Bulletin of the Geological Society of America* (1904), 15, 8-9.

⁵⁵ Waldemar Lindgren: *Trans.* (1900). 30, 578-692.

⁵⁶ *Op. cit.*, 595-597.

⁵⁷ J. D. Irving: Replacement Orebodies and the Criteria for their Recognition. *Economic Geology* (1911), 6, 619-662.

this process is believed to be of little importance in the formation of veins, and, strictly speaking, it is not a process of metasomatism. With such a method of replacement it would be impossible for the replacing material to inherit and preserve details of internal structure, regular arrangement of inclusions or the structure of organic remains. It would also be impossible for the replacing mineral to show idiomorphic boundaries, where in close contact with the partly replaced mineral. Microscopic examination of minerals that are partly altered or replaced always shows the replacing mineral to be in close contact with the earlier mineral, and, even under the highest magnification, no trace of intervening space is observable.

It has been suggested that mechanical deposition may follow so closely after dissolution as to make the two processes appear as one, but it is highly improbable that two processes could be independent and at the same time so closely synchronized. Such results might be obtained, however, if solution and deposition were interdependent, and therefore simultaneous; *i.e.*, if solution of the replaced mineral induced the deposition of the replacing mineral, or if deposition of the latter forced the former into solution.

(2) Mineral crystals in contact with supersaturated solutions must grow, and, if surrounded by other minerals, the latter will be mechanically displaced, or, if they are rendered more soluble by pressure, they may be removed in solution and deposited elsewhere. The mechanical displacement of individual minerals in a compact rock would necessitate enormous forces; the pressure per unit area would have to be very much greater than that required in separating the walls of a growing vein. The solubility of nearly all substances, so far as known, is increased by pressure and strain, and this appears to be especially true of quartz and calcite, minerals that are common in rocks subject to replacement. Therefore, when crystals develop in compact rocks, the necessary space is usually obtained through solution rather than mechanical displacement.

In his paper on "The Nature of Replacement," Lindgren draws a distinction between replacement in rigid rocks and crystallization in yielding substances. He acknowledges that in soft material "the stresses produced by crystallization may become of direct importance," but he does not believe that these forces are sufficient to make room for new crystals "in a rigid medium like quartz."⁵⁸ In support of this view he states that "the general absence of fracturing or breaking of the host mineral is evidence enough; even optical anomalies and undulous extinction are uncommon around crystals developing in comparatively rigid minerals."⁵⁸ Under his summary of previous views, Lindgren

⁵⁸ Waldemar Lindgren: *The Nature of Replacement. Economic Geology* (1912), 7, 533.

refers to the occurrence of clear gypsum crystals in clay as proof of a "force of crystallization," and then on the other hand cites "instances where the growing crystal has failed to exert this mechanical force, as in the well known calcite crystals in the sand of Fontainebleau, which include so much foreign material as to appear like crystals of sand."⁵⁹

Now these apparently contradictory phenomena are susceptible of direct experimental investigation; and the laboratory experiments of the writer demonstrate that mechanical resistance to crystal growth is only one of several factors determining whether foreign material be included or excluded by a growing crystal. The size of the pore spaces in the inclosing material is usually the controlling factor; and, in some cases perhaps, the surface tension between the solids and the solution is also of importance.

When a growing crystal is surrounded by foreign material in which the pore spaces are large, as for example in sand, the pressure is unevenly distributed over the crystal surface, growth is relatively rapid on the exposed areas while there is insufficient time for diffusion to supply additional material to the surfaces that are in contact with the foreign bodies. Therefore, the latter are gradually surrounded and included in the growing crystal. On the other hand, when the pore spaces are small, as in clay, pressure is more uniformly distributed over the crystal surface, growth is slow, and new material may reach the entire surface of the crystal by diffusion. Therefore, the foreign bodies are mechanically displaced by the growing crystal. In the so-called rigid rocks, the pore spaces are small and the growth of new crystals extremely slow; therefore, new crystals usually exclude most foreign material.

The absence of fracturing and of optical anomalies in partly replaced minerals is not, in the writer's opinion, to be regarded as proof that the growth of the new minerals was unopposed by mechanical force. Distortion and fracturing of crystals can be produced only by a differential stress exceeding the elastic limit of the substance. Pressure resulting from the growth of new minerals is developed very slowly, and in general it is transmitted through a thin layer of solution which supplies the material for mineral growth. Each mineral grain in compact rocks is surrounded by others, which increases its resistance to distortion. Moreover, strained crystals are less stable than those that are not in a state of strain; and, therefore, the replacing solutions tend to dissolve such crystals in preference to others.

New minerals that make room for themselves by exerting pressure on the surrounding material must have begun their growth in small openings filled with gas or liquid. The replacing minerals often appear as microscopic grains, completely surrounded by the older mineral.

⁵⁹ Waldemar Lindgren: *Op. cit.*, 521-522.

Sometimes minute fractures, through which the solutions probably entered, may be recognized, but often they are invisible. In many such cases, however, the presence of sub-microscopic passageways may be inferred from the fact that dots and stringers of the new mineral develop along cleavage directions in the older crystals or along the planes of fluid inclusions so common in quartz. The enlargement of new crystals is sometimes accompanied by a breaking up of the older inclosing crystals, and the substitution therefor of interlocking aggregates of smaller grains. This fact has been recognized by Lindgren,⁶⁰ though he does not attribute the fracturing to pressure from the growing crystal.

In some rocks the development of new minerals is accompanied by solution and removal of the less stable minerals and mechanical displacement of those that are more stable. Rocks in which replacement has barely begun commonly contain disseminated crystals of metasomatic pyrite, and, when these crystals are examined microscopically, it may sometimes be observed that in their immediate vicinity the more soluble minerals of the country rock, such as quartz, are relatively scarce, while the less soluble minerals, such as muscovite and chlorite, are crowded together, and in some cases bent or broken (Fig. 3).

It is difficult, if not impossible, to explain well developed crystal form in metasomatic minerals under any hypothesis except that the crystals in growing have exerted pressure on the surrounding material. The isolated pyrite crystals that develop in wall rocks usually show idiomorphic outlines; but, where pyrite has completely replaced the older minerals, crystal form is much less common, because the growing crystals have mutually interfered with the growth of one another.

The mechanical replacement of one mineral by another, in the manner outlined above, would be, necessarily, volume for volume, and not molecule for molecule. Pseudomorphs might be formed through the replacement of crystals imbedded in a matrix of more stable minerals, but it is improbable that the more minute details of internal structure could be preserved.

It is conceivable that mechanical replacement may also result when solutions dissolve the mineral that is being replaced, and thus lower the pressure on the replacing mineral sufficiently to permit additions of new material. This method of replacement may be applicable to some deposits formed in the belt of weathering, but it is improbable that primary ores in veins have been formed in this way. Primary vein minerals are deposited from solutions which, as a whole, are moving toward regions of lower temperature and less pressure, and for this reason the solutions are dominantly agents of deposition rather than of solution. This

⁶⁰ Waldemar Lindgren: Metasomatic Processes in Fissure-veins. *Trans.* (1900), 30, 615.

assumption is borne out by the general absence of solution cavities in primary replacement deposits below the belt of weathering. Even under the microscope, it is impossible to detect any intervening space between a partly replaced mineral and the replacing mineral, or other evidence that solution is dominant over deposition.

(3) When one mineral replaces another as a result of a chemical reaction, a definite number of atoms is added, subtracted, or interchanged, the number depending on the quantity of mineral replaced and the nature of the reaction. But the number of molecules that are deposited and left behind in solid form upon the completion of the reaction depends also on the solubility of the new mineral under the conditions existing at the time of its formation. In some cases the original substance is entirely removed, as when copper is replaced by silver from a solution of silver sulphate.

The new mineral formed by the reaction may be practically equal to the old one in volume, but usually the change is accompanied by either a decrease or an increase in volume. In case of a decrease, the replacing mineral is commonly porous or cellular in texture, and sometimes shows drusy cavities lined with small crystals. This is well illustrated in pseudomorphs of native silver after argentite and of smithsonite after calcite. The voids may be filled, however, through deposition of other minerals, especially in primary ores deposited by ascending solutions. When the volume of the new mineral is greater than that of the old, the surrounding material may be mechanically displaced in order to make room for the additional volume, or, more commonly, the pressure resulting from expansion may force into solution either a part of the inclosing rock or a part of the new mineral, and thus remove enough material to compensate for the increase in volume. In many cases adjustment probably results from two or more processes, and the problem may be further complicated by contemporaneous reactions involving neighboring minerals.

Irving⁶¹ and Lindgren⁶² have referred to the absence of optical anomalies in adjacent mineral grains and the lack of distorted structural and textural lines as evidence that pressure, due to increase in volume, is of little importance in the process of replacement, but with this view the writer does not agree. Pressure resulting from chemical change in the minerals of a compact rock is developed slowly, the resistance to stress is great and the solubility of most minerals is increased by pressure and strain. Therefore, it is only when relatively insoluble minerals are present that evidence of mechanical displacement or distortion of mineral crystals may be expected. Most of the arguments given above in sup-

⁶¹ J. D. Irving: *Op. cit.*, 292-293.

⁶² Waldemar Lindgren: The Nature of Replacement, *Economic Geology* (1912), 7, 531.

port of the view that the growth of new minerals in rocks may result in the development of pressure are equally applicable here.

It has been demonstrated experimentally that chemical reactions, similar to those producing changes in the minerals of rocks, may be accompanied by the development of pressures due to expansion in volume; and that these pressures may be many times the crushing strength of the material as ordinarily determined. An experiment has been described in which a porous porcelain cup containing anhydrous cupric chloride was ruptured through the formation of the hydrous salt.⁶³ Similarly, a glass bottle of 150 c.c. capacity, having walls with a minimum thickness of 1.5 mm., was fractured by the expansive force resulting from the hydration of zinc nitrate. Although such reactions are accompanied by an increase in the volume of the solid, there is usually a decrease in the volume of the system (the anhydrous salt plus water); and, where this is true, pressure can have no direct effect in preventing the reaction. The pressure developed is therefore limited solely by the resistance offered to expansion.

In many metamorphic rocks, quartz has disappeared from places subjected to maximum stress, and recrystallized where the stresses were least, while at the same time minerals, such as mica, which are less soluble, have been bent and displaced. Evidence has been cited elsewhere in support of the view that chrysotile veins may be due to the solution of serpentine under pressure resulting from its formation and the deposition of the material as chrysotile at places where the forces opposing expansion were sufficiently feeble. The general absence of vugs in chrysotile veins may be due to the pressure under which they are formed, since drusy cavities are not uncommon in fibrous veins of other minerals, such as calcite and gypsum.

The metasomatic replacement of a rock is often the result of extremely complicated processes, partly mechanical and partly chemical. In the case of individual minerals it may be impossible to determine whether replacement was the result of mechanical processes, or of chemical interchange, or, perhaps, of both combined. It is realized that such processes can never be classed as wholly chemical or wholly physical, for replacement of any kind involves the removal or addition of atoms; but, nevertheless, it is believed that the distinction outlined above is important. Silica is pseudomorphic after calcite, and commonly replaces fossil shells in such a way as to preserve the minutest details of internal structure; but, on the other hand, perfectly formed quartz crystals sometimes develop in crystalline limestone. In both cases calcite is replaced by silica, though the two processes are evidently different. It is suggested that the first is primarily a chemical process and due to chemical interchange, while the second is chiefly mechanical.

⁶³ Stephen Taber: *Op. cit.*, 76.

VI

The segregation of mineral matter originally dispersed through the surrounding material and its deposition in relatively concentrated masses through some process of replacement is of common occurrence. In this way nodules and layers of chert or flint are formed in calcareous rocks, and pyrite is segregated as single crystals, or as larger crystalline aggregates. It is conceivable that some bedded veins and veins paralleling contacts might be formed in this manner, but it is highly improbable that well defined tabular deposits could develop transverse to the rock structure. Such veins have been recognized by LeConte,⁴⁴ and classed under the heading of "veins of segregation." They can be distinguished from the replacement veins described above only by determining that the vein minerals were derived from the inclosing rock and were not introduced along fractures or similar channels. For most veins the evidence is overwhelmingly against the hypothesis that the ore minerals were derived from the immediate wall rock. Many of the arguments used by Posepny and others in combating the old lateral secretion theory of Sandberger are applicable here, and need not be repeated. Most veins are also formed along fractures or other structural planes which have facilitated the circulation of ore-bearing solutions, and thus controlled the form of the deposit. The irregular and nodular form of some of the magnesite veins occurring in serpentine suggests that they may have been formed partly in this way.

Some tabular and lenticular ore deposits, inclosed in igneous rock, and commonly regarded as magmatic in origin, should possibly be classed as veins, and included in the present discussion; for there is no essential difference between (1) the transfer of ore minerals through the agency of mineralizers set free during the final stages in the solidification of an igneous magma, and (2) the solution and transportation of ore minerals originally disseminated through a rock mass. In both cases the ore minerals may be deposited through the partial or complete replacement of earlier minerals. Through their comprehensive investigations, Tolman and Rogers⁴⁵ have established the general law that sulphide minerals are among the final products of magmatic differentiation rather than the first.

SUMMARY AND CONCLUSIONS

It is obvious that all veins have not been formed in the same way, and that many veins, particularly the larger metalliferous ones, are the result of more than one method of deposition. There are gradations

⁴⁴ Joseph Le Conte: *Elements of Geology*, 234. New York (1891).

⁴⁵ C. F. Tolman and A. F. Rogers: *A Study of the Magmatic Sulfid Ores*. Leland Stanford Junior University Publications (1916).

between the different types of veins and also between veins and other types of epigenetic ore deposits. It is the opinion of the writer that the methods of ore deposition herein discussed are applicable to all such deposits.

All minerals deposited in veins or other orebodies occupy space previously filled by other material, either gaseous, liquid, or solid. Minerals are deposited in openings filled with gas or liquid, where such spaces are available, but only very small open spaces are believed to exist at the depths where most ore deposits have been formed. It has been demonstrated that yawning fissures are not necessary for the formation of veins, and the evidence indicates that very few veins have been formed wholly by deposition in pre-existing openings. All minerals are formed under pressure, and no pressure could prevent the growth of a mineral crystal the surfaces of which were in contact with a supersaturated solution. Mineral-bearing solutions, especially under conditions of high temperature and great pressure, are able to enter the densest rocks by penetrating between adjacent crystals and even along mineral cleavages and sub-microscopic fractures. The introduction of mineral matter through very small openings is probably due chiefly to diffusion through thin films of solution. The circulation of solutions is greatly facilitated by fault fractures, planes of bedding or schistosity and by porous strata; therefore, most veins are formed along such passages.

Growing veins may make room for themselves either by mechanically displacing or by replacing the wall rock with which they are in immediate contact, and there is every gradation between these two extremes. When the minerals of the country rock in contact with a vein are forced aside, other adjacent minerals are likewise displaced, and final adjustment is attained either wholly or in part through condensation of porous material, rock flowage to places of less pressure, solution and removal of unstable minerals, or recrystallization to minerals of higher density.

All veins having cross-fiber structure are lateral secretion veins which, in growing, have forced apart their own walls, but all lateral secretion veins are not necessarily fibrous. The fibrous structure is a direct result of the manner of deposition, which has mechanically limited crystal growth to a single direction.

The replacement of one mineral by another may be primarily a mechanical or a chemical process. When the process is mechanical, the solution and removal of the old mineral is induced by pressure resulting from the growth of the new; and, therefore, the volume of the replacing mineral equals the volume of the mineral replaced. When replacement results from a chemical reaction, the ratio between the number of atoms added and the number removed is constant for a given set of conditions, and the change may be accompanied by either an increase or a decrease in volume.

The importance of the fact that crystals may grow in directions in which growth is opposed by adjacent solid bodies has not been generally recognized by geologists, but it is a fact that must be taken into consideration in framing an adequate theory of ore genesis. The hypothesis that ore minerals have made room for themselves by mechanically displacing older minerals and rocks elucidates many phenomena which otherwise are contradictory. It apparently solves some of the questions which have resulted in such widely divergent views as to the origin of certain sulphide orebodies.

Inclusions of wall rock, often angular in shape, are common in most sulphide orebodies, including those which have been classed as magmatic in origin. The fragments vary in size from microscopic specks up to blocks weighing thousands of tons. In some instances their position suggests that they have been pried off the adjacent wall. Occasionally the inclusions are bent, twisted or split into smaller fragments. The high fluidity of the ore-bearing solutions (or magmas ?) is indicated by the manner in which the minerals have penetrated along minute fractures in the inclusions and in the wall rock, and yet there appears to be no tendency for the fragments to segregate under the influence of gravity. Usually there is evidence of considerable replacement, but often replacement is of minor importance. These facts are all in accord with the hypothesis that the concentration and deposition of the ore minerals has been brought about through the agency of mineralizers, and that the ore minerals have made room for themselves, in part at least, by mechanical displacement of older minerals. The facts are apparently irreconcilable under a hypothesis that attributes the introduction of the ores to magmatic injection,⁶⁶ magmatic stoping,⁶⁷ or any similar process.

As evidence accumulates, it is becoming more and more certain that the formation of ore deposits is essentially a process of orderly and progressive concentration through the agency of mineralizers, and that the different types of deposits are due largely to difference in the original magmas. The writer believes that the ores make room for themselves, in most cases, by mechanically displacing or by replacing the older minerals and rocks.

⁶⁶ H. Ries and R. E. Somers: The Pyritic Deposits Near R  ros, Norway. *Bulletin* No. 128 (August, 1917), 1075.

⁶⁷ H. M. Roberts and R. D. Longyear: Genesis of the Sudbury Nickel-copper Ores. *Bulletin* No. 134 (February, 1918), 576.

DISCUSSION OF THIS PAPER IS INVITED. It should preferably be presented in person at the Colorado meeting, September, 1918, when an abstract of the paper will be read. If this is impossible, then discussion in writing may be sent to the Editor, American Institute of Mining Engineers, 29 West 39th Street, New York, N. Y., for presentation by the Secretary or other representative of its author. Unless special arrangement is made, the discussion of this paper will close Oct. 1, 1918. Any discussion offered thereafter should preferably be in the form of a new paper.

Pyrite Deposits of Leadville, Colo.

BY HOWARD S. LEE,* LEADVILLE, COLO.
(Colorado Meeting, September, 1918)

CONTENTS

- I. Geology and Ore Occurrence.
- II. Method of Mining.
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I. GEOLOGY AND ORE OCCURRENCE

IN central Colorado is a great belt of intrusive porphyry nearly 100 miles long (160 km.), extending from the Clear Creek district on the north to Aspen on the south, which includes many of the well known mining camps of the State. Near the southern end of this belt, at Leadville, the occurrence of these intrusives is most marked, resulting in intensive mineralization and the formation of a great variety of large orebodies. During the past 40 years, Leadville has been a steady producer of gold, silver, lead, zinc, manganese, iron, and bismuth, in the forms of sulfid, carbonate and oxide ores. It is the purpose of this paper to discuss pyrite alone, which, under present economic conditions, is valuable chiefly for its sulphur contents.

The ore-bearing formation of the Leadville district consists of two beds of limestone separated by a layer of quartzite. The upper limestone is carbonaceous, and is known locally as the blue limestone. It varies in thickness from 50 to 300 ft. (15 to 91 m.). The lower limestone is Silurian, known locally as white limestone, and is about the same thickness as the upper bed. Underneath the Silurian limestone is a layer of Cambrian quartzite from 100 to 250 ft. (30 to 76 m.) thick resting on Archean granite, which forms the limit of ore deposition. As a rule, there is a sheet of white porphyry above the upper, or blue limestone; a sheet of gray porphyry is associated with the blue limestone, either in or below it, but the porphyries are not so regular as the quartzites and limestones and are not always found in their expected positions.

Throughout the district there is an elaborate system of faults and intrusive porphyry dikes, which have an important bearing on ore deposits. The writer has seen two or three orebodies which were not closely associated with either a fault or a porphyry dike, but if the minor fractures and water courses are considered as part of the fault system it is safe to say that all orebodies are directly traceable to one or both of these causes.

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The distribution of pyrite in the Leadville district is quite general; but, eliminating the smaller bodies and those containing prohibitive quantities of zinc or lead, and considering only the larger deposits commercially valuable for their sulphur, we find the chief pyritic orebodies extending in a zone approximately 6000 ft. (1828 m.) long and several hundred feet wide, from the Yak and Moyer, on the south; through the Louisville, Greenback, Mahala, Adams, and Woltone, on Carbonate Hill; across Yankee Hill, and into the Quadrilateral, Denver City, and Tip Top, on Fryer Hill.

The orebodies are replacement deposits in the limestone along some minor fracture, or contact metamorphic deposits along some porphyry dike or fault. Replacement deposits closely related to intrusive gray porphyry dikes are the most important and most prevalent. This is due to chemical conditions, such as the presence of carbon in the blue limestone, acting as a precipitant; and to structural conditions, such as the action of the porphyry dikes as dams, interrupting the flow of ore-bearing solutions, the general formation of depressions near faults, forming basins favorable to orebodies; and other minor conditions, all of which are discussed in detail by Emmons.¹

One feature of interest to a geologist is the universal presence of a shell of manganiferous siderite enclosing iron orebodies, which is particularly noticeable in the carbonaceous limestone. These siderite deposits are fully discussed by Philip Argall,² and the fact is noted that they are always closely associated with iron sulfid orebodies. The practical importance of these siderite casings is that they very often indicate the presence of ore, when approached from the outside, and mark the limits of the ore, when approached from the inside.

The pyrite, and the iron and manganese forming the siderite, undoubtedly came from the porphyries in the form of acid sulphates. As these solutions entered the limestone they became carbonated, and the well known self-destructive action of the limestone continued. During the disintegration of the limestone, the self-liberation of large volumes of carbonic acid also liberated a constantly renewed supply of carbonaceous matter which, in turn, removed free oxygen and reduced the sulphates to sulfids. This action would continue as long as any sulphur was present, after which any remaining iron and manganese would unite with the carbonic acid, forming siderite and causing the destructive action of the limestone to cease. The fact that the pyrite is surrounded by siderite would indicate that the pyrite had been deposited first, while the de-

¹ S. F. Emmons: *Geology and Mining Industry of Leadville, Colorado. U. S. Geological Survey, Monograph No. 12* (1886).

² Siderite and Sulphides in Leadville Ore Deposits. *Mining and Scientific Press* (July 11 and 25, 1914), 109, 50, 128, 148.

structive action in the limestone was continuing away from the center of the deposit; and that the formation of siderite, and disintegration of the limestone, ceased only when all sulphur was consumed and the carbonic acid was neutralized by the remaining iron and manganese.

After the pyrite was deposited, there were at least two periods of further action in which other minerals were introduced. Two periods are apparent at the Yak mine, where the pyrite was evidently deposited along a fracture system having a general northeast direction. At a later period, there was movement resulting in fracturing along a N. 15° W. course, and it is along these fractures that secondary zinc enrichment is encountered. Still later there was movement along the original northeast system where secondary silver enrichment took place. At the Denver City mine, only secondary enrichment of silver has occurred, and the ore contains no zinc or lead. The enrichment here is quite similar to conditions at the Louisville mine, in that lines of weakness developed along small dikes of porphyry. The mechanical action in both cases would be the same, the only difference being that the precipitating action of the porphyry and pyrite together would be greater, and higher values would be found along the small dikes.

The ore is a compact, fine-grained, fairly hard pyrite. Along enrichment zones, the ore is fractured and granular, while the barren pyrite is much harder. This would naturally form ribs of harder material between ore shoots, which in many cases have been left in lieu of timbers.

II. METHOD OF MINING

In the past, the method of mining has been to drive exploratory drifts to locate the zones of enrichment, and the walls. As soon as this preliminary information was obtained, stoping was started, using the ordinary square-set method with selective mining. If it was found too expensive to hold the more or less barren pyrite in place, it was taken out and sold to the smelters for what little gold or silver it might contain as well as for the iron. In two or three cases, notably at the Yak and Leadville Unit, it was found more profitable to mine the entire orebody, since the zones of enrichment were small but frequent, and the mass was quite heavy. In this way the unit costs were reduced, the tonnage increased, and the total profit returned was greater than if the richer parts had been gouged out and the larger part allowed to remain in place.

III. VALUE IN THE MANUFACTURE OF SULPHURIC ACID

Because of the small amount of sulphuric acid manufactured and consumed in Colorado, and the high freight rates to the eastern part of the country, which precludes competition with eastern and Spanish pyrites, no great amount of Leadville pyrite has been used in the manu-

facture of acid, although small shipments have been made for a number of years to the Western Chemical Manufacturing Co. of Denver, and to E. I. Du Pont de Nemours & Co., at Louviers, Colo. Occasional trial lots have been shipped east, which have roasted satisfactorily. Unfortunately, it is not the policy of the Western Chemical Manufacturing Co. to give out information concerning their practice, so that no comparison of methods and results with Leadville pyrite and with Spanish pyrite can be made through this company, but the fact remains that they have used and are still using a good deal of Leadville pyrite satisfactorily.

The following information was given by D. S. Robinson, Superintendent of the Du Pont plant at Louviers, Colo.:

Our experience with eastern pyrite has been somewhat limited, but, as a general statement, we would not hesitate to say that the Leadville pyrite roasts fully as well as eastern pyrite, both as to being free running and in ease of obtaining almost a dead roast. Our ore is crushed to a maximum size of $\frac{1}{4}$ in. diameter. The small amount of sulphur left in the cinder is contained in those lumps which do not disintegrate to any extent during roasting. The burners are the five-hearth Wedge type with central shaft and stirring arms or rakes. The pyrite maintains its own combustion.

We have burned pyrite from a number of mines in the Leadville district, and in one case only was the arsenic high enough to interfere with our process for the manufacture of sulphuric acid. Any arsenic in excess of 0.2 per cent. makes the ore unfit for the manufacture of sulphuric acid as carried on at our Louviers plant.

All pyrite shipments from Leadville in the past have been run-of-mine and no attempt has been made to deliver a sized product. The ore was crushed to suitable size for sampling and subsequent roasting in "fines" burners. For this reason, no reliable information is available concerning the roasting qualities of lump pyrite. The writer made certain tests in an assay furnace with lumps as large as 6 in. in diameter, with which more or less violent decrepitation occurred, particularly in the larger lumps. This may have been due to excessive heat and to the fact that the heat was not applied gradually. It is also probable that an excessive amount of fines would be made during the handling of lump ore. At any rate, larger experiments under proper conditions are necessary before anything definite can be said regarding the value of Leadville pyrite as lump ore.

During 1917, about 2000 short tons of run-of-mine pyrite were shipped to the Western Chemical Mfg. Co. from the Tip Top mine, the average sulphur content of which was 48.31 per cent. Since the ore was sold for sulphur only, no further analyses of the control samples were made, but a number of mine samples were analyzed, showing less than 1.0 per cent. zinc, trace of lead, less than 0.1 per cent. arsenic, and 1.5 per cent. insoluble. During 1918, 5000 short tons of pyrite were shipped to Denver and to smelters from the Denver City and Quadrilateral claims. The average contents of this ore was:

	Per Cent.		Per Cent.
Sulphur.....	48.0	Arsenic.....	Trace
Iron.....	45.0	Lead.....	Trace
Manganese.....	2.0	Lime.....	Trace
Insoluble.....	2.2	Moisture.....	1.24
Zinc.....	0.6		

Two lots, of approximately 100 short tons each, contained 50 per cent. sulphur, and one lot contained 51.2 per cent. sulphur.

At the Greenback, Louisville, and Yak, several carloads of pyrite have been shipped to various acid plants, containing from 42 to 49 per cent. sulphur. The ore in the southern part of the district contains more zinc and insoluble than that in the northern part, but not enough to interfere with its use in the manufacture of sulphuric acid, provided care is exercised in mining to eliminate portions containing zinc.

Following are freight rates from Leadville to some of the eastern and Middle West cities where pyrite is used:

Valuation of \$5 and under

	Per Ton (2000 Lb.)
Leadville to Colorado common points.....	\$1.50
(Colorado common points are Denver, Colorado Springs, and Pueblo.)	

Valuation of \$20 and under

Colorado common points to Chicago.....	\$4.45
To Mississippi River common points.....	3.65
To Memphis.....	4.45
To Nashville.....	6.10
To Pensacola.....	4.00

It has been a general practice with local acid manufacturers to sell calcined residues to Colorado smelters. This could be done profitably because the smelters have always had an excess of siliceous ores and iron has commanded a premium.³ Unfortunately, there is no place in the Middle West where residues can be sold, and if there is any metal value in the residue it must be returned to Colorado smelters for treatment. This is now being done with certain residues from Kansas and Oklahoma zinc smelters. An average pyrite containing 40 per cent. iron in excess of silica, and 45 per cent. sulphur, will roast with a loss of 30 per cent. in weight and an increase in the iron to 56 per cent. The proportion of silver and gold in the residue will also increase in the same ratio. The iron credit will pay the treatment charges, so that the net cost of treatment is the return freight to Denver, Salida, or Pueblo. Since all

³ See Report of Smelter and Ore Sales Investigation Committee—State of Colorado, 1917.

Leadville sulfids contain some gold and silver, the sale of residues is to be considered as entirely practical, where the original ore contains 4 oz. or more silver, or its equivalent in gold.

IV. SUMMARY

There are large deposits of pyrite in Leadville, containing a minimum of 43 per cent. sulphur, suitable for the manufacture of sulphuric acid. In these deposits, there are enrichment zones containing gold, silver, and zinc, but the system of mining in use will permit selective methods whereby the portions more valuable for other metals may be stoped separately and shipped to the smelters while the pyrite is kept clean for acid use.

The only material available now is run-of-mine ore suitable for crushing and roasting in "fines" burners. The problem of lump ore, both as to suitability and preparation, will be worked out only when there is sufficient demand to warrant experiments.

The returning of residues from a pyrite originally containing precious metals to the value of, say, \$2 per ton, after calcination in the Middle West, for smelting in Colorado, is financially practicable.

DISCUSSION OF THIS PAPER IS INVITED. It should preferably be presented in person at the Colorado meeting, September, 1918, when an abstract of the paper will be read. If this is impossible, then discussion in writing may be sent to the Editor, American Institute of Mining Engineers, 29 West 39th Street, New York, N. Y., for presentation by the Secretary or other representative of its author. Unless special arrangement is made, the discussion of this paper will close Oct. 1, 1918. Any discussion offered thereafter should preferably be in the form of a new paper.

The Tailing Excavator at the Plant of the New Cornelia Copper Co., Ajo, Ariz.

BY FRANKLIN MOELLER,* M. E., CLEVELAND, OHIO

(Colorado Meeting, September, 1918)

CONSIDERING the really short time that has elapsed since hydro-metallurgical processes of extracting copper from ores have been extensively developed, and the large scale on which this method is practised at Ajo, the successful operation of the plant must excite the admiration of every visitor.

The application of the mechanical unloader to the purpose for which it is employed at Ajo is but an extension of the use for which it was originally designed, some 20 years ago, for unloading iron-ore vessels at the lower lake ports. At a time when the maximum output of a single machine, with men shoveling the ore into buckets, did not exceed 40 tons per hour, G. H. Hulett invented and constructed a mechanical unloader with a bucket of 10-ton capacity. This machine was of the steam hydraulic type, and it is still in operation after nearly 20 years of service.

Several more machines of the same type were built, but the difficulties of power transmission, and the rapid development of electrical machinery, soon led to the adoption of electrically operated machines, and practically all of the later installations have been thus equipped. This electrically operated unloader has proved so well fitted for the work that the design of the lake boats has been practically revolutionized, with special view to the ease and rapidity of unloading. It is now possible to unload a 12,000-ton vessel with four machines in a little over 2 hr. This has necessitated an increase in the capacity of the machine, and the largest yet built handles an average load of 17 tons, with a possible maximum of 20 to 21 tons.

The Ajo excavator is somewhat simpler in design than the iron-ore unloader, in that it is not provided with a larry. In the unloader, the iron ore, picked up by the bucket, is delivered to a larry or transfer car which runs in the lower chord of the bridge; the larry then delivers the ore either into railroad cars, standing on several parallel tracks, or into the stock pile, thereby saving the time that would be required for the bucket to make the trip. At Ajo, the bucket delivers the tailing

* Engineer, Power and Mining Dept., The Wellman-Seaver-Morgan Co.



FIG. 1.—LEACHING PLANT, NEW CORNELIA COPPER CO., AJO, ARIZ.

directly into cars, and as the distance is short, the capacity of the machine is limited only by the regularity with which the cars can be supplied.

The leaching tanks from which the tailing is to be removed are 12 in number, arranged in two parallel rows. Each tank is 88 ft. (26.8 m.) square, and, when filled to a depth of 14 ft. 6 in. (4.42 m.), holds 5000 tons of ore; one tank is emptied every day. The excavator has a span of 106 ft., just sufficient to clear the buttresses on both sides of the tanks. Beyond the bridge runway, on one side of each set of tanks, are the railroad tracks for the cars which take the tailing to the dump. To move the excavator from one row of tanks to the other, a transfer table is provided, having a runway at right angles to the bridge runway of the excavator.

The excavator consists essentially of four parts: the bridge, the trolley, the walking beam, and the bucket.

The bucket is of the two-part type, and each shell is given a considerable sliding action during the closing movement, thus acting as a hoe and insuring a more nearly complete filling of the bucket when approaching the bottom of the pile. When open, the distance between the cutting edges of the shells is over 20 ft. (6 m.). The shells are U-shaped, without back-closing piece, so that the bucket can

always be closed without choking. The opening and closing chains are attached to cam-shaped drums, rotated by gearing and rope drum located in the vertical leg to which the bucket is attached. The bucket



FIG. 2.—TAILING EXCAVATOR AT WORK ON A TANK.



FIG. 3.—TAILING EXCAVATOR DISCHARGING.

can be rotated about the axis of the bucket leg through an arc of about 325° in either direction, and as the center of the bucket is offset about 2 ft. from the center of the bucket leg, it can clean up, in any given

position, a space 24 ft. (7 m.) in diameter. The driving mechanisms for all the bucket movements are located on the end of the walking beam opposite to that where the bucket leg and bucket are attached. The mechanism for raising and lowering the bucket is also located in the walking beam and consists of a motor-operated drum from which four ropes lead around sheaves, to the framework of the trolley, back again to the walking beam, and are anchored there.

The use of the walking beam has several advantages: it provides a ready means for balancing the weight of the bucket; it eliminates the hinged cantilever of the bridge; and its length can be adjusted to suit



FIG. 4.—TAILING EXCAVATOR WORKING AT THE BOTTOM OF THE TANK.



FIG. 5.—TAILING EXCAVATOR WORKING AT THE TOP OF THE TANK.

special requirements. In order to insure vertical movement of the bucket, the bucket leg is fitted with parallel rods. The forward or bucket end of the walking beam is not entirely balanced, and the downward movement of the bucket is due to gravity, but is always under the control of the operator. A solenoid brake on the motor holds the bucket in any position.

The main trolley to which the walking beam is pivoted is mounted on two six-wheel spring-bearing trucks located immediately under the pivot posts. The rear end of the extended trolley is fitted with upper- and under-running wheels to prevent this end of the trolley from lifting.

The trolley is moved by a rack and pinion operated by a motor-driven mechanism, and is supported on a moving bridge, both legs of which are mounted on two four-wheel equalizing spring-bearing trucks, one of each set being provided with driving gears. The wheels are double flanged, and the trucks have ball-and-socket connections to allow for full equalization. One of the trucks is also provided with an expansion bearing to permit the bridge structure to adjust itself to inequalities of the track

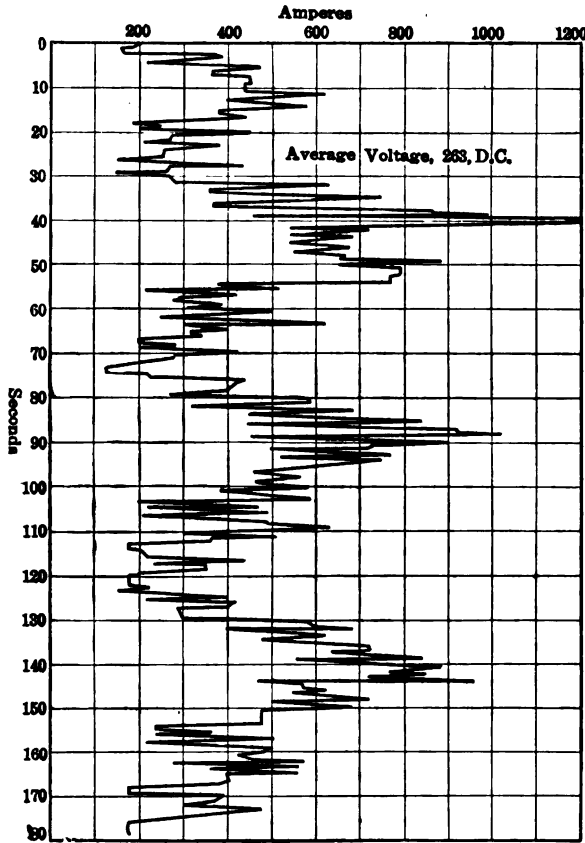


FIG. 6.—POWER DEMANDS OF EXCAVATOR DURING THREE MINUTES.

gage. Power is applied to the trucks in the customary manner, the motor for driving the bridge being located in its lower chord.

All of the movements of the bucket are controlled from one point by a single operator, who is situated in the bucket leg, immediately above the bucket. He can thus manœuvre the bucket with perfect accuracy and assure the maximum output of the machine. One movement, that of the bridge, is not controlled from the bucket leg, but the operating levers for this are so located that they can be reached by the operator when at about

the middle of the bridge. It is customary for an assistant to look after the oiling, and have general oversight of the various mechanisms. All told, about 500 hp. of direct-current motors are required for operating the machine, and the several switchboards are grouped in the main trolley. Safety appliances are provided wherever possible, both electrical and mechanical, and every precaution has been taken to avoid interruptions to service. The machine will handle 500 tons of tailing per hour, which is equivalent to a bucketful every 72 seconds.

To avoid injuring the bottom of the tanks, the tailing is removed only to within 6 in. (15 cm.) of the bottom. Men are then sent down to shovel the remainder into windrows so that at the next excavation the greater portion of this tailing will be removed. The tailing is delivered into 20-ton cars, running on a track parallel to the line of the tanks, and the operators become so adept in manipulating the discharge of the bucket that practically nothing is spilled outside of the cars or back into the tanks.

The actual amount of current required per ton of material is extremely low, and the accompanying chart gives a clear picture of the power demands. It frequently happens that the operator combines the closing, lifting, and traveling movements and by doing so creates a heavy peak demand.

It is interesting to note how the cost of discharging ore has been cut by improved methods. When steam hoists were first used, the cost was 40 c. to 50 c. per ton. With the introduction of the bridge system, this was reduced to 18 c. to 20 c. per ton, and with the present type of machine, the cost varies from 4 c. to $5\frac{1}{2}$ c. per ton. This cost includes superintendence, repairs, maintenance of apparatus and dock, and sundry contingent funds.

The transfer table is of simple construction, consisting of two eight-wheel trucks connected by a steel structure, and operated by an 80-hp. motor, giving the table a speed of 75 ft. per minute. The transfer table is fitted with latches to insure proper registering of the table tracks with the excavator tracks, and its movements are controlled from a cab located on the table.

TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS
[SUBJECT TO REVISION]

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The Elko Prince Mine and Mill

BY J. V. N. DORR,* B. S., E. M., NEW YORK, N. Y., AND L. D. DOUGAN,† B. S.,
MIDAS, NEV.

(Colorado Meeting, September, 1918)

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GEOLOGICAL CONDITIONS

THE Elko Prince mine is in the Gold Circle district, Nevada, about 1½ miles (2.4 km.) from the town of Midas, 55 miles (88.5 km.) west of Battle Mountain and 50 miles (8.5 km.) northeast of Golconda. The district

* President, The Dorr Co.

† General Superintendent, Elko Prince Mine.

is described by Emmons in U. S. Geological Survey *Bulletin* 408, 1910. Little was said of the Elko Prince, however, as only a small amount of work had then been completed.

The geological structure of the region is simple. The oldest exposed formation, covering most of the area, is rhyolite, which has a light-colored devitrified groundmass enclosing phenocrysts of feldspar, quartz, and magnetite. It has been somewhat weathered and partially stained with oxide of iron. There are several outcrops of andesite which cut the rhyolite. The ore deposits occur as fissure veins, replacement veins, and sheeted zones. The Elko Prince vein is of the first type. The rhyolite near the veins is silicified, stained with oxide of iron, and, at some localities, replaced by ore, or is so permeated by metals as to be classed as ore. The vein filling consists chiefly of quartz, and the values consist entirely of gold and silver. Part of the gold exists as the native metal and part is associated with pyrite. Silver occurs free and as argentite in banded streaks through the vein. These veins trend in a northwesterly direction, with dips varying from 65° to vertical.

DEVELOPMENT OF THE ELKO PRINCE PROPERTY

Gold was discovered in the district in the Fall of 1907, and a characteristic rush followed. The town of Midas was laid out and shortly had 2000 inhabitants. Several small mills were built, one of which, the Rex, ran several years. After the first excitement, the people drifted away rapidly, and at present only about 150 remain. The Elko Prince claims were located in 1907 by Paul Ehlers, a prospector, and 10 claims were patented in 1913 after considerable development work had been done. The property was purchased in 1908 by the Elko Prince Mining Co., L. L. Savage, President, and was extensively developed between 1911 and 1915.

The outcrop of the Prince vein is insignificant, only a narrow seam of low-grade quartz, or an obscure fissure containing no quartz or metals. The first work on the property was a 60-ft. (18-m.) shaft sunk on the cropping. A narrow seam of mineralized quartz was followed, but nothing of importance was found; then a 240-ft. (73-m.) drift on the vein gave similar results. Later, a 700-ft. (213-m.) crosscut reached the vein 270 ft. (82 m.) below surface, and cut an ore shoot almost in the center. Subsequent work developed a vein having an average width of 14 to 15 in. (35.5 to 38 cm.), a total tonnage of 30,000, and a gross value of approximately \$1,000,000, the limits of the orebody being quite well defined.

In June, 1915, the Elko Prince Mining Co. made an agreement with the Dorr Co., whereby the latter was to design, finance and build a cyanide mill of at least 40 tons daily capacity, furnish additional mine equipment,

and operate the property until certain financial results had been attained. Milling was begun in November, 1915, and the original terms were completed in June, 1917, but the Dorr Co., operating through the Elko Prince Leasing Co., has continued in charge of the property to the present time.

THE PRINCE VEIN

The Prince vein has a uniform northwest-southeast strike and a dip varying from vertical to 85° to the northeast. One horizontal fault of a few feet occurs in the 1400 ft. (426 m.) of development on the property, and a second, of much greater extent, probably occurs just beyond the south end line.

The vein filling is hard but brittle quartz, with a very small amount of sulphides. Partial oxidation extends from the surface to the deepest openings. Manganese in oxidized form is found in spots. No enrichments due to leaching and redeposition have been observed, except as to a small portion of the silver. The gold is mainly free but very fine; about 50 per cent. can be amalgamated. Thin flakes of native silver are found in the footwall and penetrate its seams in places to a depth of an inch. The silver exists chiefly as argentite and polybasite, giving the quartz the characteristic banded appearance that usually accompanies the presence of these minerals.

A characteristic analysis of the ore is:

	Per Cent.		Per Cent.		Per Cent.
SiO ₂	85.0	S.....	0.1	Ignition loss.....	2.0
Al ₂ O ₃	2.0	As.....	0.1	Cu.....	0.0
Fe.....	3.0	Sb.....	0.1	Au (oz. per ton)...	0.7
CaO.....	4.0	Mn.....	Trace	Ag (oz. per ton)...	10.0

A second vein, the June Bell, is parallel to the Prince, and lies a short distance to the west. It is of the same type but much smaller, and gives promise of producing but little metal.

The development of the Prince vein at the time milling began is shown in Fig. 1, the dotted lines indicating the extent of ore estimated as profitable. Above the 300-ft. (91-m.) or main level, mining has confirmed the accuracy of the estimate. Below the 300-ft. level, the orebody has been proved to extend slightly further to the north, considerably further to the south, and some little ore has been found below the 600-ft. level.

MINING PRACTICE

Stoping

The following conditions influence the method of mining. The vein is almost vertical; its average width is 15 in. (38 cm.) seldom less than 12

or more than 24 in. thick; the west wall is smooth, hard, and firm, with quartz sometimes frozen to it; the east wall is less well defined, decomposition having extended into it to a depth of a few inches to two or three feet; a sliding movement has occurred in the east side of the vein, and at some points a considerable amount of gouge is found, containing pieces of vein matter.

When planning a method of mining, stripping (resuing) was considered, the idea being to mine the east wall as narrow as possible, use it for filling, break the ore away from the west wall, and run it all out. The vein, however, was too brittle in many places to permit this; all of the quartz in the gouge would have been lost, as well as much of the vein proper. The advantages of this method—the small amount of high-grade ore to be milled, and the smaller plant to be erected—were more

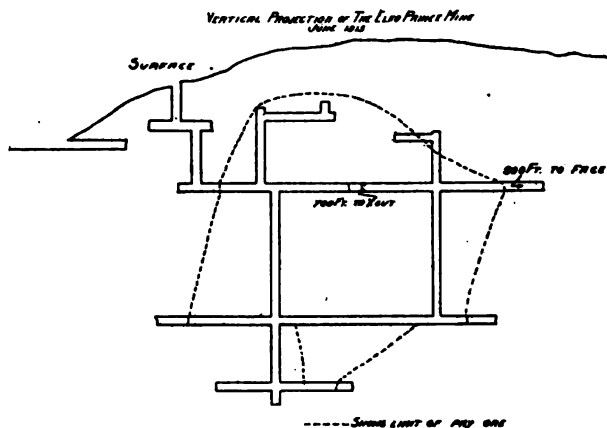


FIG. 1.—DEVELOPMENT OF THE ELKO PRINCE VEIN, JUNE, 1915.

than offset by the greater cost of mining and the inevitable losses. Stopping the ore with some waste, as little as possible, required a plant of 25 to 50 per cent. greater capacity, and involved a small increase in power and supplies consumed, but this method permitted the recovery of all of the ore, and it was thought that the increased milling expenses would be less than the loss by any selective method of mining.

Overhead stopping was adopted, enough ore being drawn daily to maintain proper working room above the broken ore. No sorting was attempted in the stopes. In spite of the fact that the stopes were almost vertical, and that one wall was hard and smooth, the ore would occasionally hang and cause trouble. After a time, it was found that if a little ore was drawn daily from every shoot, and the broken ore was not permitted to remain at rest for a whole day, it would remain loose enough to run freely.

Predictions as to the most efficient stoping width ranged from 30 in. to 48 in. (76 to 121 cm.); it has been found possible and practicable to maintain an average stope width of 32 in. throughout the mine. Above the 300-ft. level, the average was 28 in.; in many places, the miners broke only 20 in., but the ore would not draw freely through such narrow stopes. Fig. 2 shows a typical stope, with good walls.

At the north end of the shoot, where the ground was quite dry, the



FIG. 2.—A STOPE BETWEEN THE 450 AND 600-FT. LEVEL.

stope was carried from the 600 right through to the 300 level. At the south end, where rather wet, an intermediate level at 450 was found advisable.

Drilling

Five 16 V Waughs, supplied with $1\frac{1}{8}$ -in. (28.6-mm.) cruciform steel, are used in stoping. Drifting and sinking are done with Waugh clipper drills using $\frac{7}{8}$ -in. (22.2-mm.) hollow steel. A pressure of 85 lb. of air is maintained at the drills.

Contract Stopping

Mining was first done on straight day's pay; but, within a few months, a bonus system was adopted whereby a premium, increasing with each 5 ft. (1.5 m.), was paid on all footage drilled in excess of 50 ft. per day. Before initiating that system a careful record was kept of the work of each man for two months, in order to secure a basis for a just bonus. It was understood that no change in unit prices would be made thereafter, regardless of the amount that might be earned. It is most important for the success of any bonus system that the men shall recognize that the whole saving, as compared with day's labor, is to be divided with them, and that the system is not to be designed for the purpose of reducing them to the standard wages of the camp. It was found that some men, on contract, would break twice as much ground as when on day's pay. There was some



FIG. 3.—AN ORE CHUTE.

tendency to place holes too close together if the ground was easy for drilling. Straight contracting was finally adopted, based on the square foot of vein area broken; the contractors are obliged to keep the walls free from ore and maintain the stopes within limits designated by the foremen. The company furnishes the powder and the men do the shooting. The usual price in such contracts is from 12 to 15 c. per square foot, at which rate the men make from 25 to 75 per cent. more than day's pay.

Loading and Tramming

The chutes on each level are spaced about 27 ft. (8 m.) apart, and are equipped with the gate shown in Fig. 3. By having the gate boards ex-

tend across the end of the chute, they can be knocked open at either side, without binding.

The mine cars are 30-cu. ft. (0.85 cu. m.), Truax side-dump cars weighing 1100 lb. One man and a horse readily handle 60 tons a day with an average haul of 1100 ft. (335.28 m.), using a five-car train from the 300-ft. drift to the mill bins. Hand tramming is done on the lower levels, two men handling the full tonnage.

Hoisting

The selection of hoisting equipment was determined by the following considerations:

1. The shaft followed the changing dip of the vein, making rapid hoisting dangerous.

2. It was expected that, with the size of engine available for the power plant, this would be fully loaded, making a high load factor imperative.

3. With the small tonnage, the saving of a single man meant a large cut in the cost per ton.

A Denver Engineering Works' double-drum electric hoist, with counterweight, was selected. It is driven by a 10-hp., 550-volt, d.-c. motor, and has a hoisting speed of 150 ft. per minute. The complete cycle takes 5 min. from the 600-ft. to the 300-ft. level. The self-dumping skip weighs 1200 lb., and has a capacity of 35 cu. ft. The trammers dump their cars directly into the skip through a chute.

Timbering

When the mill started, the need of ore required drawing faster than shrinkage stoping allowed, and the miners were obliged to work on stulls. Trench jacks were found advantageous for this purpose, as they could be removed before shooting and put back into place much quicker than stulls. The main timbering now consists of chutes, manways, and stulls in the stopes as the ore is drawn. The wet, sticky nature of the ore in the narrow stopes causes the ore to pull nearly vertical over the chutes, and thus requires close stulling, but light pieces, such as 3 by 4's or 4 by 6's, are sufficient in most places. Very little timbering is required in the drifts.

Cost of Mining

Mining costs for 1917 are given in Table 1, covering a total of 21,674 tons, or 59.4 tons per day. The costs do not include prospecting for additional orebodies.

TABLE 1.—*Mining Costs per Ton for 1917*

Timbering and chutes.....	\$0.5588
Blacksmith.....	0.0995
Stoping.....	0.8083
Tramming.....	0.2822
Hoisting.....	0.1956
Air.....	0.1288
Powder, caps, and fuses.....	0.4452
Repairs.....	0.0486
Drill steel.....	0.0570
Miscellaneous.....	0.4987
Total.....	\$3.1227

Note: Miscellaneous includes local supervision, assaying, insurance, taxes, and sundry miscellaneous items.

MILLING PRACTICE

General Design

The financial arrangements allowed the mill to be designed so that when the orebody already developed had been worked out and the plant scrapped, the greatest net profit would have been made. The treatment of 50 tons of sorted ore daily promised a life of about $3\frac{1}{2}$ years, with the chance of an extension by finding other orebodies or obtaining custom ore.

Labor was scarce in the district, and, although there was no labor union, the Tonopah scale of \$4 minimum for 8 hr. had been paid.

Redhouse, on the Western Pacific, the nearest freight station, is 34 miles away, and hauling by wagon costs from \$13.50 to \$15 per ton. The road from Redhouse to Midas is a good desert road, with a large increase in grade in the last 5 miles. The chance of heavy snow at the upper end in Winter, and the certainty of very heavy hauling in Spring, make it essential to stock up by December to run until May. Hauling by team has proved more satisfactory than by motor truck. Oil storage of 22,000 gal. was provided at the mill. No electric power was available.

Although the ore is a hard quartz, a variable quantity of very slow-settling gouge occurs with it, so that it was necessary to provide a large settling area per ton. The treatment, shown in Fig. 4 and 5, follows the standardized lines of ball-mill crushing and fine grinding, with countercurrent decantation and zinc-dust precipitation. As this pulp cannot be thickened to less than 60 to 65 per cent. moisture, a dewatering filter is used to enable the tailings to be conveniently handled, and to reduce mechanical losses of cyanide and metal.

Fig. 6 shows a plan of the mill, with many of the details omitted, but with flooring and runway elevations indicated; Fig. 7 shows one elevation.

It will be noted that the working floors are nearly at one level, and that the machines requiring close attention, such as the Diesel engine, the filter, etc., are grouped near the center of the main building, where they can be under observation from any point where the operator must work. This arrangement, feasible only in a small plant, enables one man to keep general watch over the whole operation of fine grinding and cyaniding, as well as the power plant for mine and mill; so that, while two men are used on the two night shifts as a matter of precaution, the mill man frequently sends his helper to the crusher room for a few hours, when short of ore.

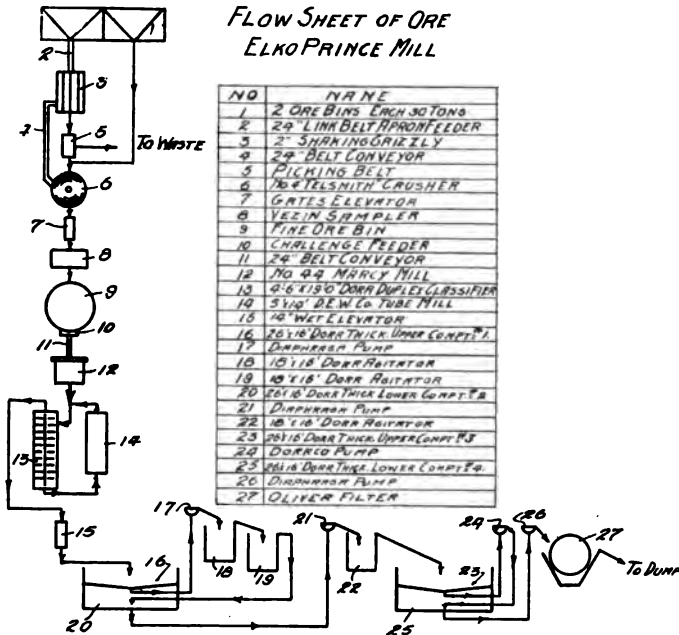


FIG. 4.

When not so required, the shift men do a good deal of repairing, and prepare the samples for the assayer.

The relative elevations of the fine-grinding and cyaniding departments are of interest. If the objection frequently urged to the elevation of pulp had been considered, and a gravity flow from the classifier to the first thickener had been attempted, the cost of the excavations and the building would have been much greater, the convenience of operating diminished, and additional pumping of clear solution would have been needed. We consider a well designed wet elevator to be at least as efficient as a pump.

Except this one elevation of combined ore and solution, it will be noted that in all elevations, some other necessary purpose is accomplished

as well. For instance, the diaphragm pumps, transferring the thick pulp, also serve to regulate its discharge; and the clarifying-filter and precipitation-press pumps serve to elevate the solution to the last and highest thickener, from which it flows through the others and through the grinding system back to the elevator.

The use of the closed-type Dorr tray thickener (Fig. 9) with the flow in series, makes each tank do the work of two, and cuts the necessary settling-floor space in half. The advantage of saving mill space in this case is unusually important as coal costs \$26 per ton and the waste heat from the oil engine is entirely relied on to heat the mill.

Normal operation requires only one storage tank (the gold tank) for solutions, as No. 3 thickener serves as a mill-solution supply tank, and the barren solution flows directly to No. 4 thickener. There should be, however, a sump or reserve tank large enough to take the contents

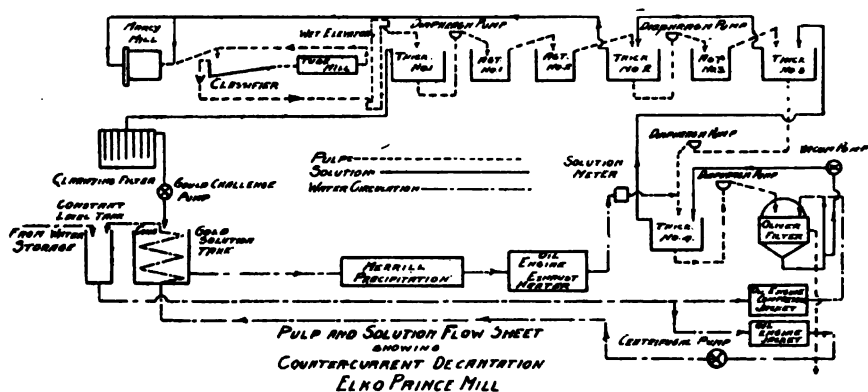


FIG. 5.

of a thickener, to avoid possible loss of solution in case of an accident: such a tank could be outside the mill.

Coarse Crushing

Two 10 by 12-ft. (3 by 3.6 m.) receiving bins, with 50° bottoms lined with No. 10 steel, hold 30 tons of ore each. No. 1, located only 60 ft. (18 m.) from the mouth of the tunnel, is covered with a grizzly made of 30-lb. rail, with 7-in. (177.8 mm.) spacing. It has a 24-in. (60.9 cm.) Link-belt feeder discharging to a shaking grizzly. The undersize goes to the elevator by belt conveyor; the oversize goes to an 8 ft. by 30-in. Jeffrey steel-pan picking belt, traveling 3 ft. per min., then to a No. 4 Tel-smith gyratory crusher. From 5 to 10 tons of \$2 waste per day is sorted out. No. 2 bin, used for custom ore, discharges directly into the crusher. The crusher has given good service; the chilled-iron mantle lasted two years, and the concaves are still good. We believe that the installation of this more expensive crusher equipment, which is standard for large mills,

is well worth while even at a small mine, on account of the saving of labor and the uniform crusher feed; one man usually crushes and sorts the whole tonnage. The Gates dry elevator, at 55° slope and belt speed of 120 ft. (36.5 m.) per min., has been very satisfactory on the wet, sticky ore of the mine.

A Vezin sampler, with intermediate crushing to $\frac{1}{4}$ in. (6.35 mm.) through a Samson crusher, after the first cut, is used on custom ore and to check feeder samples on company ore. It cuts out $\frac{1}{5}$, $\frac{1}{10}$, and $\frac{1}{10}$.

The crushed-ore bin is a 15 by 15-ft. (4.57 by 4.57 m.) steel cylinder on a wood platform, having an 18-in. (45.72 cm.) center discharge to a Challenge feeder, which delivers to a 12-in. belt conveyor leading to the Marcy mill. An opening in the side of the bin, at the bottom, about 3 ft. high and 30-in. wide, and extending like a tunnel about 4 ft. toward the center so that no ore will flow out, allows access to the inside of the bin for loosening sticky ore.

Fine Crushing

The Marcy mill discharges to a Dorr classifier in closed circuit with a tube-mill, the classifier sands being returned to the tube-mill by a screw conveyor. The solution overflowing No. 2 thickener is divided between the Marcy mill, the classifier, and the tube-mill. For satisfactory extraction a product containing not more than 1 per cent. coarser than 100 mesh, and at least 78 per cent. finer than 200 mesh is required.

TABLE 2.—*Fine-crushing Data*

MARCY MILL	TUBE-MILL
Size, No. 44	Maker, Denver Eng. Works
Speed, 36 r.p.m.	Size, 5 by 14 ft.
Ball load, 2200 lb.	Speed, 23 r.p.m.
Size of balls, 4 to 5 in.	Pebble load, 14,000 lb.
Maximum size of feed, 2 in.	Size of pebbles (Danish flint), 4 in.
Maximum size of discharge, $\frac{1}{4}$ in.	Rate of crushing, 133 tons per day
Rate of crushing, 54 tons per day	Power, estimated, 35 hp.
Power, estimated, 25 to 35 hp.	Water in feed, 35.1 %
Water in feed, 39.4 %	Scoop feeder, 30 in. radius
Liners, manganese steel	Liners, Komata
Grates, chrome steel	
DORR CLASSIFIER	
Model "C" Duplex	
Size, 18 ft. 8 in. long by 4 ft. 6 in. wide	
Slope, 2 in. per foot	
Speed of rakes, 14 strokes per min.	
Depth of tank at overflow, 21 in.	
Water in discharged sand, 34.3 %	
Water in overflow, 8.6 parts to 1 part solids	

SCREEN TESTS

Mesh	Marcy Mill Discharge		Tube-mill Discharge		Classifier Feed		Classifier Discharge		Classifier Overflow	
	%	Cum. %	%	Cum. %	%	Cum. %	%	Cum. %	%	Cum. %
Over 10..	15.5	15.5	.....	.....	7.4	7.4	9.1	9.1		
10- 20	17.0	32.5	0.2	0.2	9.4	16.8	7.9	17.0		
20- 65	28.1	60.6	9.1	9.3	17.7	34.5	26.8	43.8		
65-100	5.9	66.5	15.6	24.9	12.0	46.5	19.4	63.2	1.0	1.0
100-150	7.0	73.5	26.6	51.5	16.2	62.7	23.5	86.7	4.1	5.1
150-200	4.4	77.9	13.6	65.1	8.9	71.6	8.5	95.2	13.4	18.5
Below 200	22.1	100.0	34.9	100.0	28.4	100.0	4.8	100.0	81.5	100.0
	100.0		100.0		100.0		100.0		100.0	

COSTS, CENTS PER TON

MARCY MILL

Balls (1.13 lb.)	9.59 c.
Liners	6.03
Repairs	4.16

CLASSIFIER

Repairs	0.03 c.
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TUBE-MILL

Pebbles (3.50 lb.)	6.84 c.
Liners	1.52

The Marcy mill (one of the earliest types) as first installed had an open scoop feed and iron-lined wooden scoop box, but this has been replaced by a self-contained scoop with end feed, which gives much better results. Cast-iron feed and center liners were unsatisfactory, and the mill is at present equipped with manganese-steel liners and a chrome-steel grate.

The tube-mill is equipped with Komata shell liners composed of manganese-steel angle bars and cast-iron filler bars and plates; the end liners are cast iron. The operation of the mill has been entirely satisfactory in every way, and the cut gears give excellent service. The life of the liners is about 18 months; the end liners last about one year.

No repairs have been required for the classifier, except the renewal of the screw conveyor flights, which last six months.

Wet Elevator

This is a standard elevator composed of 14-in. (35.56 cm.) 7-ply rubber belt, and runs at 380 ft. (115.8 m.) per min.; 12 by 6-in. Salem buckets, of No. 14 steel, are spaced 12 in. center to center. The boot is

concrete, and large enough to retain the contents of the buckets in case of a spill. The lower journals are one-half bearings, mounted in the boot but outside the housing; they are maintained at constant tension by a counterweight, and are hinged on a shaft at the back of the elevator. The oil-soaked hardwood blocks last 8 months. This boot is a design

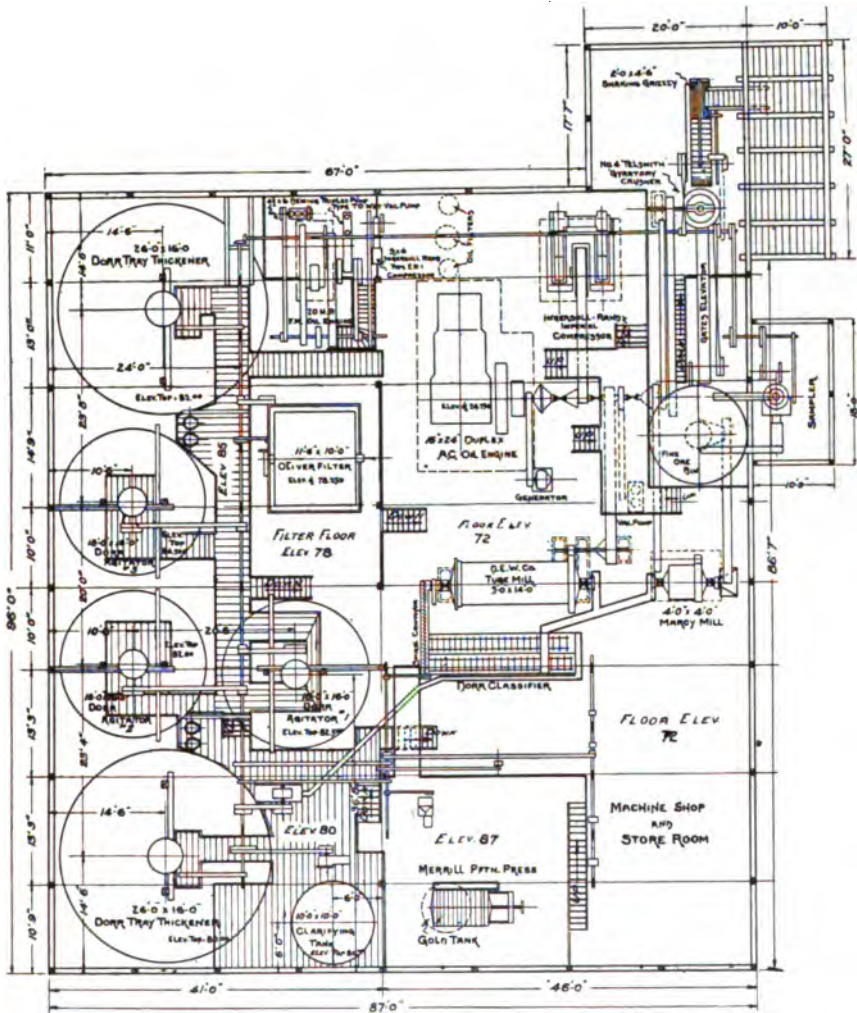


FIG. 6.—PLAN OF THE MILL, LISTING THE ELEVATIONS.

developed by N. Cunningham at the Hollinger mill, and is most satisfactory. Slipping of the belt developed as it wore, and was eliminated entirely by attaching six steel strips $\frac{1}{2}$ by $\frac{5}{32}$ in. (12.7 by 2.38 mm.) across the face of the head pulley; the strips do not injure the belt, and

probably will increase its life by preventing slippage. The first belt lasted two years, and the life of the buckets working on this fine pulp is indefinite, as the tendency to coat with lime balances the wear.

Tray Thickeners

The closed-type Dorr tray thickener is shown diagrammatically in Fig. 9. Wooden tanks 26 ft. (7.9 m.) diameter by 16 ft. (4.8 m.) stave are used and the trays are of wood, following the earlier practice. In this type the tray divides the tank into two separate compartments, with no circulation or leakage of pulp between them, the central shaft being suitably packed where it passes through the tray. Both compartments are fed, discharged, and overflowed independently, and thus two distinct operations are carried on at once. For instance, in the top compartment of No. 1. primary thickening takes place; while in the bottom, a thickening of the agitated pulp after a second dilution is accomplished.

Some trouble was experienced with the formation of "islands" in the thickeners. These are aggregations of solid pulp that build up on the arms, gradually bridging them until they extend a large way into the tank. They can readily be broken up in a standard thickener, but, as the space below the tray is not accessible, the trouble was overcome by reversing the direction of the thickener for a few minutes each day. At Aurora, Nev., the same trouble was overcome by raising and lowering the mechanism 8-in. each day.

Diaphragm Pumps

Two duplex, 4-in. center-valve pumps take the discharge from the thickeners. They have an adjustable stroke and make 50 strokes per minute. Very close adjustment is made by admitting air to the suction. The diaphragms last from 4 to 6 months.

Agitation

Three standard Dorr agitators are used in wood tanks 18-ft. diameter by 16 ft. high. Each gives 24 hours' agitation with normal tonnage and dilution. They operate at 3 r.p.m., and only enough air circulation to prevent segregation is needed. Drag chains on the distributing launders prevent building up of solids on the tank sides. A 9 by 6-in., 100-cu. ft., low-pressure, Ingersoll-Rand, Rogler type compressor supplies air for the three agitators, the solution meter, and for discharging the Oliver filter.

Filtration

An Oliver filter, 11½-ft. diameter, 10-ft. face, is used for final washing and dewatering. It makes a revolution in 8 min., and a 14-in. vacuum, maintained by a dry vacuum pump, gives a ⅞-in. (11.11-mm.) cake.

The pulp is fed to the filter near the bottom of the tank, maintaining a zone of clear barren solution above the pulp, which assists in washing. Barren solution wash is used on the rising side, and water on the descending. The cost for repairs has averaged 3.52 c. per ton.

Solution of Metals

The mill-feed assays from 0.6 to 1 oz. Au, and from 7 to 14 oz. Ag per ton. Figures for March, 1918, taken as typical, show that, on the basis of bullion plus tailings, there was an extraction of 97.5 per cent. of the gold and 87.1 per cent. of the silver. These figures are representative of results obtained on Elko Prince ore; but, in the treatment of

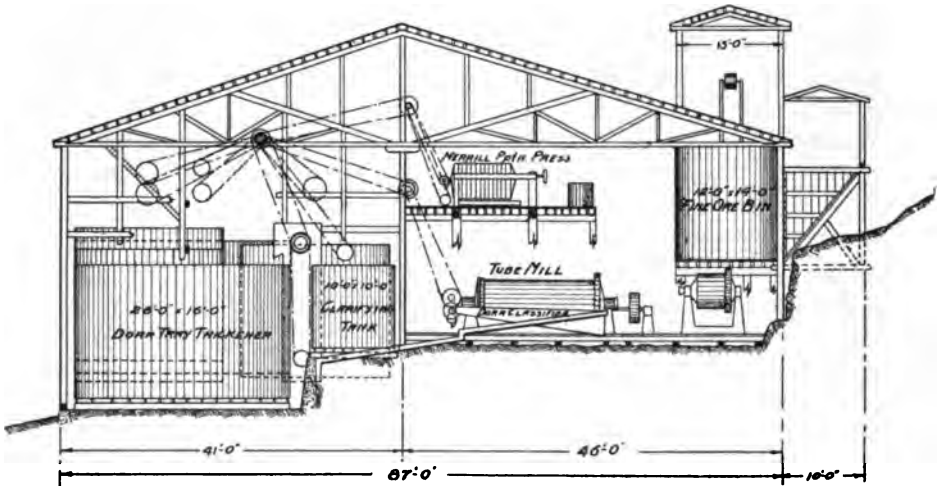


FIG. 7.—A SECTION THROUGH THE MILL.

custom ore, variations in extraction and chemical consumption are large. Table 3 shows the distribution of the extraction among the different units in the process. The figures were obtained by sampling over a period long enough to eliminate individual errors.

TABLE 3.—*Extraction, Per Cent.*

Unit	Gold	Silver
Tube-mill.....	80.0	48.3
Thickener No. 1.....	3.5	8.2
Agitator No. 1.....	9.0	22.2
Agitator No. 2.....	2.0	3.1
Thickener No. 2.....	0.7	0.8
Agitator No. 3.....	0.8	3.0
Thickener No. 3.....	0.6	0.2
Thickener No. 4.....	0.3	0.5
Oliver Filter.....	0.6	0.8
Total.....	97.5	87.1

The benefit from change of solution is more evident on the silver than on the gold; the silver also shows the effect of contact with a solution diluted by the fresh water added at the filter. It has been a common experience, both in sand leaching and filtration, that when the commercial extraction has been obtained, and a final displacement water wash is added, a further amount of metal dissolves just when it cannot be economically recovered. The use of excessive wash water, and its precipitation before wasting, reduce this loss.

Silver at \$1, instead of 50 c. per ounce, as when the mill was built, requires a careful study of the chance for increasing extraction, but capital expenditures now are necessarily curtailed by the high cost of equipment and by the limited amount of ore remaining in the mine. An additional tray thickener would give a slight increase in solution and a decrease in dissolved loss. The solutions now are heated only by waste heat, but it is possible that direct heat, in spite of its cost, would be profitable. Lead acetate was used first, but was replaced by litharge with equal results and lower cost; about 1.5 lb. per ton of ore gives the most economical results. Working tests have not indicated that finer crushing or longer agitation would be profitable.

The dissolved loss depends on the grade of the ore and the efficiency of precipitation. While the barren solution can be maintained at 4 c. or less, the loss is below 8 c. per ton (Ag at \$1); but, if precipitation gives trouble and the barren solution goes to 4 to 8 c., the loss jumps to 8 to 15 c.

Cyanide is added to the tube-mill feed, the strength being maintained at 2.3 lb. NaCy per ton of solution; the strength in the agitators is 2 lb. NaCy. The mechanical loss of cyanide is about 0.6 lb., and the chemical consumption about 0.5 lb. per ton of ore. Lime is maintained at about 0.6 lb. per ton of solution in the tube-mill and about 0.4 lb. per ton of solution in the agitators.

The consumption of materials is tabulated in Table 4. It has recently been found possible to reduce the lime, and profitable to increase the litharge.

TABLE 4.—*Consumption of Reagents, Pebbles, and Balls in 1917*

	Lb. per Ton of Ore	Cost per Ton of Ore
Sodium cyanide.....	1.10	\$0.2866
Lime.....	11.71	0.2152
Pebbles.....	3.50	0.0684
Balls.....	1.13	0.0959
Zinc.....	1.08	0.2093
Litharge.....	0.44	0.0598

Clarifying

The overflow from thickener No. 1 goes to the clarifying filter, which is in a 3-in. (76-mm.) redwood tank, 10-ft. (3-m.) diameter by 10 ft.

high. Across the top of this tank a 3-in. header carries connections for 24 filter leaves, only 18 of which are in use. Each is $5\frac{1}{2}$ by 4 ft. and made with 12-oz. canvas. The leaves are connected to the header by short lengths of $\frac{1}{2}$ -in. iron pipe, $\frac{3}{4}$ -in. hose and Butters quick opening clamps. A Gould's 7 by 6-in. Challenge pump draws the solution through the filter and discharges it into the gold tank.

Precipitation

The amount of solution precipitated daily is 280 tons as measured with a Tanner meter; pregnant solution assays from \$3 to \$5 per ton, and



FIG. 8.—VIEW OF THE ELKO PRINCE PROPERTY.

the barren solution from 2 to 6 c. A Merrill precipitation press with 14 frames, 52 by 3 in., is used with a Merrill zinc-dust feeder, and operated by a Deming triplex pump.

Both Merrilite and Colorado zinc dust have been used, and it appears that, under the Elko Prince conditions and costs, the latter is more economical. The cost for zinc dust during 1917 was \$0.2093 per ton of ore milled, or approximately \$0.04 per ton of solution precipitated; the actual consumption of zinc dust was about 0.212 lb. per ton of solution precipitated, or 0.12 lb. per ounce of bullion produced. The Crowe

vacuum precipitation equipment, controlled by the Merrill Metallurgical Co., has recently been installed and the results of the first 2 months show a saving in zinc dust of about 50 per cent.

Refining

The press is cleaned up once or twice a month. Acid treatment is unnecessary, as the dry precipitate contains 75 to 85 per cent. gold and silver and gives a bar 950 fine. Drying to 15 per cent. moisture is done in an oven heated by the exhaust gases of the Diesel engine. A press, made by the Illinois Supply & Construction Co., forms the product into briquets of 3 in. diameter and weighing 2 lb. each, at the rate of 12 per minute.

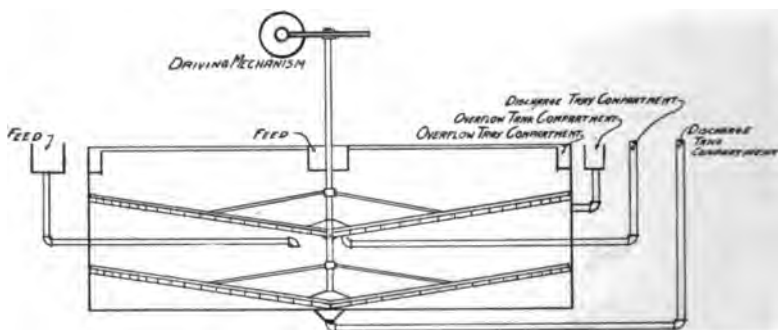


FIG. 9.—DIAGRAMMATIC DRAWING OF DORR CLOSED-TYPE TRAY THICKENER. (Patented.)

Melting is done in a Duplex Monarch tilting furnace with Lindsey burners. The flux contains 12 of nitre, 8 of borax, and 4 of silica, and the usual cleanup handles 2000 lb. of briquets, yielding 1500 lb. of bullion.

Heating

The mill is heated entirely by radiation from the engine and solutions, and can be maintained at a comfortable temperature through zero weather. The barren solution is heated by passing through a Williams Tool Co. heater, connected to the engine exhaust, on its way to thickener No. 4. Additional heat is obtained by circulating the engine and compressor jacket water through the gold tank, and by using water at 90° F. from the Diesel engine and compressor for replacement water in the filter. This maintains a temperature of 75 to 85° F. during treatment, at no cost.

Water Supply

Water is pumped from a well below the town of Midas, a distance of 11,000 ft. with a lift of 700 ft. A crude-oil engine was first installed, but it required so much attention that it was replaced with a 10-hp. motor; the water pipe is used as the return electrical circuit.

Cost of Milling

Some of the milling costs for 1917 have been given before. A complete statement is shown in Table 5.

TABLE 5.—*Cost per Ton for Milling 20,087 Tons in 1917*

	Repairs		Operating		Totals
	Material	Labor	Supplies	Labor	
Crushing and sorting.....	0.011	0.029	0.010	0.142	\$0.192
Grinding and cyaniding.....	0.177	0.112	0.172	0.305	0.766
Chemicals.....			0.771		0.771
Power (a).....	0.040	0.038	0.355	0.090	0.523
Water.....			0.037	0.015	0.052
Assaying and sampling.....			0.027	0.093	0.120
Office and supt.....			0.040	0.150	0.190
Insurance and taxes.....					0.113
Refining.....			0.045	0.025	0.070
Miscellaneous operating.....			0.020	0.035	0.055
Miscellaneous repairs.....	0.031	0.139			0.170
Totals.....	0.259	0.318	1.477	0.855	\$3.022

(a) The charge for power includes fuel and lubricating oils, one-half the time of millman, and all repair labor and materials. It is allocated to milling, water, mine air, hoisting, and mine development, according to estimated power distribution.

THE POWER PLANT

As electric power was not available, and coal was too expensive, an oil engine was the only motive power considered. A 150-hp. Fairbanks-Morse engine on the property might have furnished a large part of the power needed; but, as fuel oil cost 12 c. per gal. delivered, and the rated consumption of the engine was double that of a Diesel, the initial saving would have been lost in operating.

The choice finally lay between an Allis-Chalmers Diesel and a De la Vergne semi-Diesel; the Diesel was selected. While both are excellent engines, one point of comparison between the two may interest possible users. The Diesel feeds the charge of oil, against no pressure, into a cup from which it is atomized by 700 lb. air, while the semi-Diesel sprays a mixture of oil and air, against heavy pressure, into the cylinder. It has proved possible to keep a valve tight, discharging air alone under high pressure, for 6 to 12 months; whereas, when spraying a mixture of air and oil, the makers only claim that the valve should remain tight a month, and our experience at another plant showed that, on account of loss of efficiency when they begin to leak, it is advisable to regrind valves every 7 to 10 days.

First cost, economy of attention, and saving of waste heat suggested one unit for mine and mill, with a small gasoline engine for circulation of the pulp in case of a shutdown. The mill plan shows the main line shaft driving all the heavy equipment, including the tube-mill, Marcy mill, mine compressor, crusher, hoisting dynamo, and the dry vacuum pump for the Oliver filter. A parallel countershaft drives, through a bevelled gear, the slow-speed line shaft for the thickeners, classifier, agitators, diaphragm pumps, elevator, etc.

The engine has a rating of 180 hp. at sea level, or 145 hp. at the altitude of the mill. It has two 12 by 24-in. cylinders, and requires about 170 gal. of 24° Bé. oil per day. Ample lubrication has been found essential. The oil filter furnished with the engine was replaced by a De la Vergne oil reclaimer which has given much better satisfaction, entirely eliminating the free carbon in the oil, so that twice the amount is fed to the bearings, with less consumption.

It was found that the best temperature for the circulating water in the engine cylinders was 110° F. This proved entirely too high for the best results in the compressor, as the lubricating oil carbonized rapidly, so that a separate circuit, discharging water at 90° F., was installed for the compressor.

It has not been possible to measure the power output per gallon of fuel used, but as the engine radiation, the jacket water, and the exhaust are all used to heat the mill and solutions, the total efficiency in Winter must be very high. The exhaust gases have been frequently as low as 110° F.

CONSTRUCTION COSTS

The following figures, representing costs of construction in 1915, are, unfortunately, only of historical value to-day.

Mill, complete (including power-plant).....	\$67,509.06
Refinery	2,560.11
Oil storage and wagons	2,162.05
Office, assay office, and other buildings and equipment	8,071.48

Total surface expenditures, except water line already installed. \$80,302.70

The total cost of the mill machinery and tanks, at shipping point, was \$33,647.18, checking rather closely the common estimate that a mill erected will cost double the cost of its machinery.

The lumber, 205 M. costing \$48 per M. at the site, cost \$20.42 per M. to erect. Machinery, 145 tons, cost \$22.40 per ton to install; and 10 tons of piping was placed for \$44.77 per ton.

DISCUSSION OF THIS PAPER IS INVITED. It should preferably be presented in person at the Colorado meeting, September, 1918, when an abstract of the paper will be read. If this is impossible, then discussion in writing may be sent to the Editor, American Institute of Mining Engineers, 29 West 39th Street, New York, N. Y., for presentation by the Secretary or other representative of its author. Unless special arrangement is made, the discussion of this paper will close Oct. 1, 1918. Any discussion offered thereafter should preferably be in the form of a new paper.

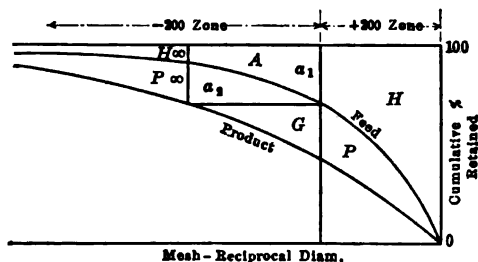
Crushing Resistance of Various Ores

BY LUTHER W. LENNOX, E. M., VICTOR, COLO.

(Colorado Meeting, September, 1918)

DURING the last few years, one of the great problems in the milling of all ores has been that of crushing. This subject involves not merely the cost of the operation, but also the selection of the proper degree and character of crushing to yield the best metallurgical results on the given ore. Considering the diversity of machinery, one is led to wonder at the variety of crushing methods employed, even when realizing that metallurgy demands varying products.

In an attempt to investigate the relative crushing resistances of a number of ores now being milled in this country and Alaska, the management of the Portland mills requested samples of average mill-run of ore

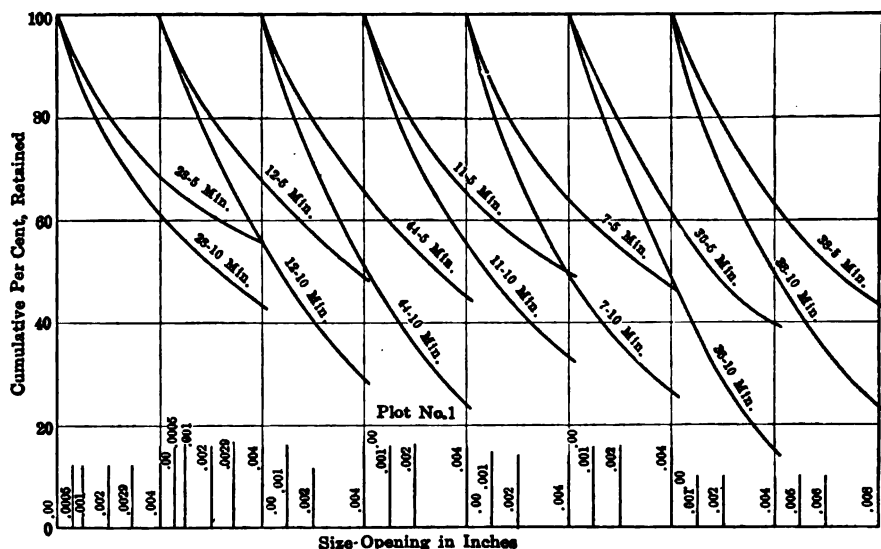


from various companies. The request met with a ready response, indicating the desire of all operators to gain information on the subject.

The difficulties involved in this investigation were numerous, lack of time for outside problems during this strenuous period being a serious one. Also, we were unable, in the time, to obtain a correct 150-mesh screen; in the screen analyses tabulated and plotted herewith, the 150-mesh screen was used merely to protect the 200-mesh screen, not to ascertain points on the curves.

The experimental crusher was a small iron tube-mill, 8 by 12½ in., in which was placed a definite number (74) and weight (3450 gm.) of ¾-in. steel balls, 1 lb. water and 1 lb. ore. To obtain uniform conditions, each ore was first crushed and screened, and from the sized products a "standard feed" was artificially prepared, the same standard being adopted for all tests in that particular series. The prepared feed was

placed in the little mill, and this was allowed to revolve at 84 r.p.m. for a definite time; the sample was then dried and screened. The whole operation was then repeated for other periods of time.



ditions identical, the screen tests of the products should at least give an indication of the relative crushing resistances of the ores. One objectionable feature is the small size of the crusher, although the labor in-

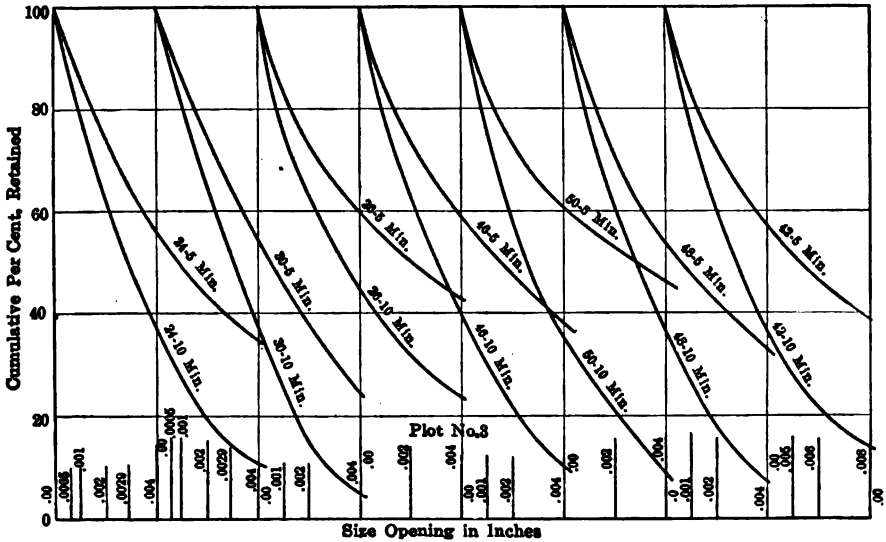


FIG. 3.

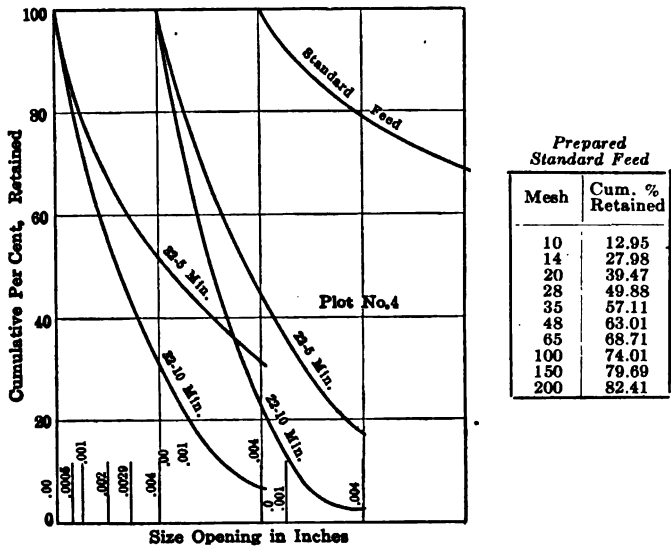


FIG. 4.

involved in drying, cutting down, and screening the product of a larger machine would be burdensome. The small size also necessitated a comparatively fine feed.

The method adopted for computing the results is that of Rittinger, based on the law that work done in crushing is proportional to the surface exposed by the operation, or to the reciprocal of the diameter. For plotting the screen tests, the mesh (reciprocal of diameter) and the cumulative per cent. of oversize are used as coördinates. The area

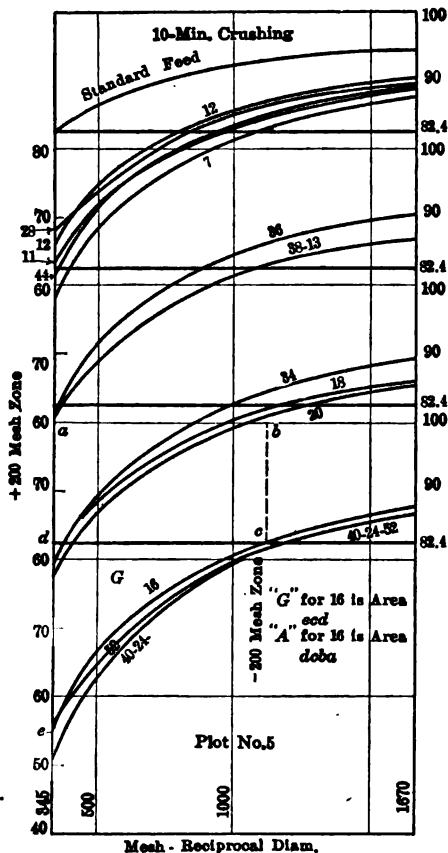


FIG. 5.

accurate as to *absolute* results, but only that it yields additional evidence as to the *relative* crushing resistances of ores.

Product work (Rittinger's law) = $H + P + G + a_1 + a_2 + H\infty + P\infty - (H + a_1 + H\infty) = P + G + a_2 + P\infty$. (See diagram, p. 1255.)

For a given ore, assume that the material in the feed (say 20 per cent.) below 200 mesh has the same value in mesh-tons as the finest 20 per cent. in the product, that is,

$$a_1 + H\infty = P\infty + H\infty, \text{ or } a_1 = P\infty$$

Substituting this value for $P\infty$, and calling $(a_1 + a_2) = A$,

$$\text{Product work} = P + G + A$$

between the feed and product curves will be proportional to the "apparent work" done. The apparent work is in turn inversely proportional to the resistance of the ore to crushing; hence, the area between the curves is inversely proportional to crushing resistance.

Unfortunately, we are unable to deal accurately with the material below 200 mesh, which is where most of the work done is represented. Microscopic measurements seem to offer the only accurate method. Curves plotted in the area below 200 mesh seem to follow no definite law, as that of a hyperbola. Many operators may feel but little interest in what happens after a certain fineness (say 48 mesh) is reached, but this does not alter the necessity of measuring the total work done on the whole of the ore.

As a method of measuring the work done in the region below 200 mesh, I offer the following suggestion, not asserting that it is

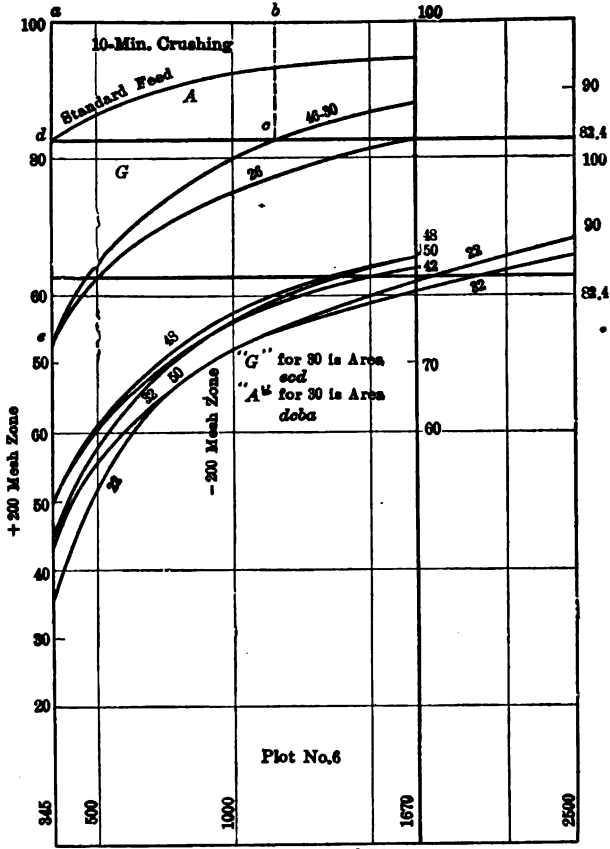


FIG. 6.

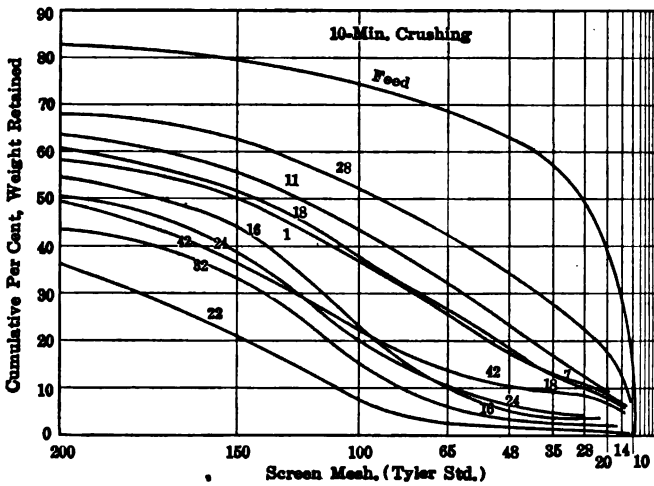


FIG. 7.

TABLE 1.—*Screen Analysis of Product from 5-min. Crushing—Cumulative Per Cent. Retained on Screen*

Mesh	Opening, Inch	28	12	44	11	7	36	38
10	0.065	4.07	4.07	3.88	6.57	5.85	1.79	3.70
14	0.046	19.08	9.35	9.51	14.72	12.78	4.55	8.39
20	0.0328	26.29	13.98	13.50	20.45	18.67	6.89	11.80
28	0.0232	34.06	20.81	19.15	27.10	24.12	11.39	16.91
35	0.0164	41.24	29.63	26.33	34.34	30.32	18.60	23.78
48	0.0116	48.40	38.83	35.79	41.58	36.87	29.44	33.56
65	0.0082	55.27	48.41	44.66	49.33	46.06	39.67	42.83
100	0.0058	62.29	58.11	55.03	57.78	55.19	51.12	52.90
150	0.0041	69.77	68.37	66.24	66.75	64.59	63.93	59.57
200	0.0029	74.32	74.14	72.95	71.77	70.09	70.93	70.35

Mesh	40	34	52	13	16	18	24	20
10	3.47	2.91	3.96	3.24	2.85	5.41	3.59	4.41
14	9.76	6.77	9.07	7.91	6.91	12.86	8.30	11.20
20	13.74	9.68	13.30	11.65	9.59	18.32	11.12	15.98
28	23.32	14.24	19.57	17.38	13.15	24.51	14.40	21.82
35	28.11	20.36	27.17	25.11	17.69	30.81	18.96	27.95
48	34.97	29.13	36.47	33.49	25.91	38.37	26.03	35.49
65	43.26	38.46	44.91	42.13	35.75	45.49	34.18	43.29
100	52.86	48.89	53.81	51.35	47.82	53.67	44.48	52.64
150	59.26	62.27	63.87	61.35	60.94	63.28	56.81	62.01
200	69.40	68.22	68.83	67.79	67.68	68.51	65.36	68.29

Mesh	26	46	42	30	50	48	22	32
10	5.18	1.77	4.99	0.44	1.17	0.71	0.22	2.15
14	12.10	4.87	11.76	1.41	2.63	1.81	0.60	5.14
20	16.82	7.35	16.26	2.05	3.96	3.63	0.97	6.96
28	22.38	11.71	20.57	2.86	6.83	5.44	1.67	9.67
35	28.00	18.66	25.14	4.79	11.92	9.50	3.43	13.71
48	35.25	28.79	31.42	11.86	21.59	19.35	8.71	21.84
65	42.23	37.39	38.02	23.78	33.19	30.96	16.64	30.28
100	50.87	48.74	47.50	40.59	45.82	43.77	29.27	41.72
150	60.97	61.64	53.55	56.84	53.92	50.89	46.53	53.77
200	66.24	66.38	65.68	64.86	65.97	61.26	55.80	59.88

TABLE 2.—*Screen Analysis of Product from 10-min. Crushing—Cumulative Per Cent. Retained on Screen*

Mesh	Opening, Inch	28	12	44	11	7	36	38
10	0.065	6.11	1.98	1.94	3.68	3.67	0.48	2.02
14	0.046	13.77	3.91	4.19	7.65	7.17	1.19	4.31
20	0.0328	18.12	5.05	5.34	10.01	8.97	1.50	5.34
28	0.0232	22.54	6.63	6.71	12.88	10.81	1.85	6.44
35	0.0164	27.53	9.86	9.35	16.90	13.27	2.53	8.22
48	0.0116	34.71	17.12	15.08	23.08	17.29	5.31	13.76
65	0.0082	42.57	28.04	23.13	32.14	25.65	14.15	22.49
100	0.0058	51.92	41.78	36.20	43.27	36.76	30.08	35.31
150	0.0041	62.91	56.83	52.46	55.90	50.22	51.07	44.86
200	0.0029	68.25	65.48	61.73	63.55	58.07	60.84	60.74

Mesh	40	34	52	13	16	18	24	20
10	2.20	0.93	1.66	1.22	1.32	2.65	1.50	2.35
14	5.65	2.11	3.47	2.79	2.71	6.19	2.96	5.70
20	7.23	2.64	4.40	4.25	3.24	8.07	3.62	7.44
28	8.42	3.19	5.39	5.56	3.68	10.17	4.06	9.16
35	9.76	4.08	7.05	7.90	4.01	12.93	4.55	11.40
48	12.77	6.79	12.13	13.13	5.44	18.45	6.16	15.87
65	17.92	14.04	20.90	22.18	10.34	27.22	10.54	24.12
100	28.05	28.45	34.20	35.08	23.22	37.79	20.36	35.39
150	35.81	50.06	48.22	50.60	44.24	51.59	38.04	49.52
200	50.19	58.91	55.89	60.60	54.82	59.58	50.44	58.21

Mesh	26	46	42	30	50	48	22	32
10	3.47	0.70	2.76	0.33	0.33	0.24	0.22	0.77
14	7.43	1.58	6.29	0.66	0.66	0.55	0.51	1.65
20	9.51	2.02	7.64	0.79	0.79	0.70	0.75	2.00
28	11.33	2.46	8.48	1.19	0.92	0.88	0.99	2.29
35	13.35	2.99	9.19	1.39	1.12	1.12	1.23	2.55
48	17.63	4.80	10.73	1.83	2.20	2.24	1.78	3.48
65	23.01	9.87	13.84	4.81	7.03	6.39	2.88	6.29
100	32.79	23.02	22.94	16.90	22.13	19.89	7.06	15.39
150	45.09	41.82	31.06	40.85	33.33	30.91	21.38	32.74
200	53.51	52.03	49.33	52.27	44.99	49.85	36.36	43.48

TABLE 3.—General Data

Ore No.	Mesh-tons Above 200 Mesh Area P			Mesh-tons Area G			Mesh-tons Area A			Total Mesh-tons P + G + A			Comparative Crushing Resistance	Source of the Ore
	5 Min.	10 Min.		5 Min.	10 Min.		5 Min.	10 Min.		5 Min.	10 Min.	Average		
28	3,840	6,830				2,900	4,400	8,980		9,040	18,710	13,870	1.33	Calumet & Hecla jig tails.
12	5,360	10,070		1,000		2,870	4,400	8,280		10,760	21,220	15,990	1.16	British Columbia, Tonopah-Belmont Development Co.
11	5,180	9,590		1,530		4,300	5,800	10,550		12,510	24,440	18,470	1.00	Portland mill feed.
44	6,200	11,420		1,200		4,350	5,000	11,000		12,400	26,770	19,580	0.94	Smuggler Union.
36	7,620	13,160		950		4,150	5,000	9,500		13,570	26,810	20,190	0.92	New Cornelia Copper Co.
38	7,190	11,670		1,670		5,270	5,800	12,700		14,660	29,640	22,150	0.83	Liberty Bell.
7	6,020	11,300		2,050		6,150	6,950	13,000		15,020	30,450	22,730	0.81	Butte & Superior.
34	7,910	13,530		1,950		5,470	5,900	11,300		15,760	30,300	23,030	0.80	Humboldt mine (Smuggler Union).
13	7,300	11,850		2,280		5,760	6,300	12,700		15,880	30,310	23,090	0.80	Tonopah-Belmont.
18	6,380	11,050		2,050		6,400	6,200	14,400		14,630	31,850	23,240	0.79	Goldfield Con., cyanide feed.
20	6,960	11,420		2,200		7,880	7,220	16,200		16,380	35,500	25,940	0.71	Goldfield Con., flotation feed.
52	6,750	12,550		2,100		8,520	7,050	14,950		15,900	36,020	25,960	0.71	Alaska Treadwell, quartz & schist.
16	8,450	14,360		2,100		8,050	5,990	13,550		16,540	35,960	26,250	0.70	Miami Copper Co.
40	6,900	13,700		2,070		8,850	7,050	14,950		16,020	37,500	26,760	0.69	Alaska Gold Mines Co.
24	9,070	15,000		2,890		8,850	7,560	14,950		19,520	38,800	29,160	0.63	Homestake, unaltered ore.
46	8,350	14,800		3,200		8,960	8,600	14,450		20,150	38,210	29,180	0.63	Arizona Copper Co.
30	10,950	15,530		3,200		8,960	7,560	14,450		21,710	38,940	30,320	0.61	Nevada Con., pit ore.
48	10,240	15,630		4,380		10,800	10,550	17,800		25,170	44,200	34,680	0.53	Morenci, Phelps-Dodge.
42	8,050	14,720		3,900		12,000	11,100	20,000		23,050	46,720	34,880	0.53	Calumet & Arizona, roaster ore.
26	7,470	12,900		3,520		12,190	10,750	23,500		21,740	48,590	35,160	0.52	Alaska Treadwell, schist.
50	9,350	15,830		3,300		12,400	9,330	29,400		21,980	57,630	39,800	0.46	Copper Queen, mill feed.
22	13,290	18,900		7,680		18,100	14,060	24,400		35,030	61,400	48,210	0.38	Utah Copper.
32	10,390	16,650		7,550		17,800	18,160	28,000		36,100	62,450	49,270	0.37	Ray Consolidated.

I have plotted the diameters and cumulative per cents as coördinates. The last definite point in diameter is 0.0029 in. (200 mesh); the curves must also pass through the point corresponding to 100 per cent. retained and zero diameter. The last three known points—0.0082 or 65 mesh; 0.0058 or 100 mesh; and 0.0029 or 200 mesh—are shown

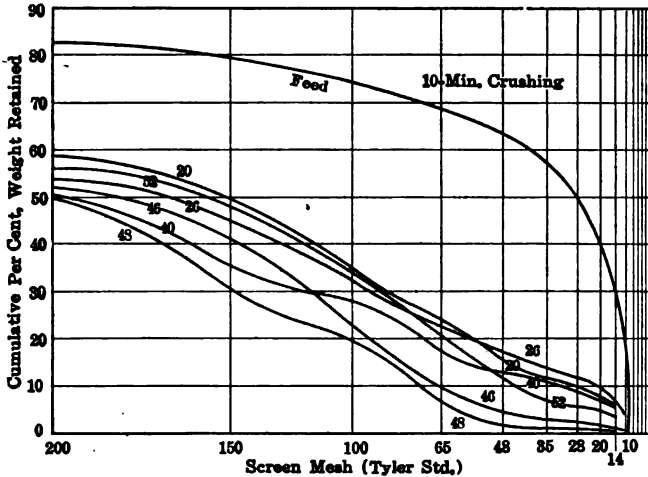


FIG. 8.

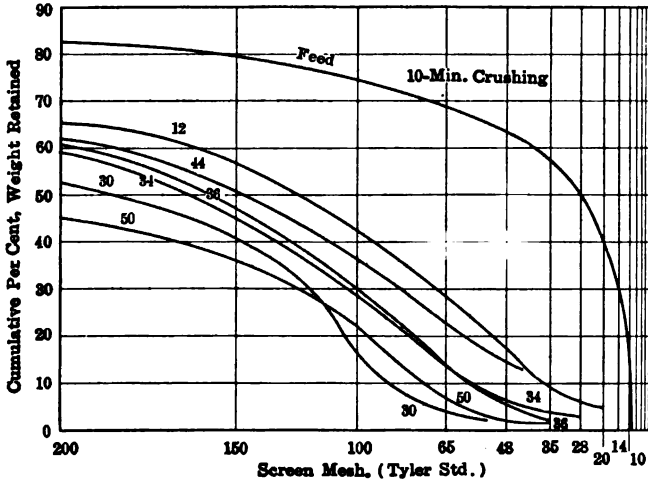


FIG. 9.

in plots No. 1, 2, 3, 4. The extension of the curves through the unknown area between 0.0029 in. and zero is made with reference to the known curve section. Subsequent investigation may require some of these curves to be slightly altered. The ratio between mesh-tons of the 5-min. and the 10-min. products does show a proportion fairly close to

1:2. From the curves thus drawn, I have taken points representing 0.0029 in. (345 reciprocal), 0.002 in. (500 reciprocal), 0.001 in. (1000 reciprocal), 0.0006 in. (1667 reciprocal), with their corresponding cumulative per cents, and have replotted these as No. 5 and 6 (only the curves for the 10-min. crushing being shown). From these curves, the so-called "product area" $G+A$, of material below 200 mesh, is

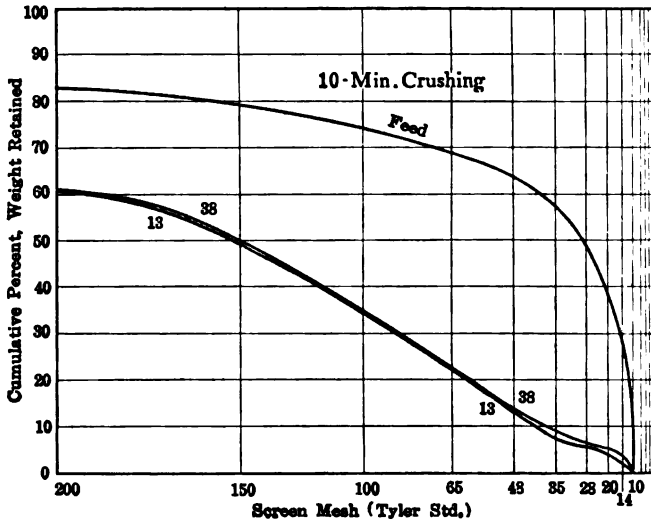


FIG. 10.

obtained; this, added to the product area P of material above 200 mesh, gives the total mesh-tons to be used for comparison with the mesh-tons of other ores. These totals are recorded in Table 3.

Screen analyses of the products after 5-min. and 10-min. crushing, starting with the standard feed of which the analysis can be observed in the diagrams, are given in Tables 1 and 2. As a matter of further interest, these analyses are plotted according to the Tyler direct cumulative diagram method in Fig. 7, 8, 9, 10.

DISCUSSION OF THIS PAPER IS INVITED. It should preferably be presented in person at the Colorado meeting, September, 1918, when an abstract of the paper will be read. If this is impossible, then discussion in writing may be sent to the Editor, American Institute of Mining Engineers, 29 West 39th Street, New York, N. Y., for presentation by the Secretary or other representative of its author. Unless special arrangement is made, the discussion of this paper will close Oct. 1, 1918. Any discussion offered thereafter should preferably be in the form of a new paper.

Roasting for Amalgamating and Cyaniding Cripple Creek Sulpho-telluride Gold Ores

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(Colorado Meeting, September, 1918)

THE Golden Cycle Mining and Reduction Co. operates its custom mill at Colorado Springs on Cripple Creek ores exclusively. These ores are straight sulpho-tellurides, with practically no base metals such as Pb, Cu, Zn, As, or Sb.

Upon entering the mill, the ore all passes through the sampler to storage bins, where beds of 5000 tons each are made to insure uniformity in roasting.

CLASSIFICATION OF ORES

For efficiency, it has been found advisable to separate the ores into two classes according to their lime content. Other constituents have their effect, such as alumina and magnesia, but, speaking generally, these are roughly proportional to the lime, which, as CaO, is used as the indicator. Class A contains not more than 2 per cent. CaO and comprises about 66 per cent. of the ore treated. Class B contains over 2 per cent. CaO, and comprises 34 per cent. of the ore treated. Typical analyses of both classes are as follows:

	Class A	Class B
Insol.....	86.70	75.90
Al ₂ O ₃	2.30	3.40
Fe.....	3.26	3.48
CaO.....	1.57	5.12
S.....	1.79	1.80
MgO.....	0.21	1.08
Ignition loss.....	3.20	6.50
	99.03	97.28

The beds of each class of ore are made as large as possible with the available ore as it comes in, to avoid changing from one bed to the other any oftener than necessary. Each roaster will handle 50 per cent. more of class A ore than of class B, with practically the same results. This necessitates changing the rate of feed for each new bed and tends toward a poor roast and loss of tonnage at each change.

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CRUSHING PREPARATORY TO ROASTING

After leaving the storage bins, the ore is crushed in Schmidt "kominuters," ball-mills. Diagonal slotted screens $\frac{3}{8}$ by $\frac{1}{2}$ in. (3.57 by 12.7 mm.) are used, giving a product which analyzes as shown in Table 1.

TABLE 1.—*Screen Analysis of Ball-mill Product*

Size	Old Screens		New Screens	
	Per Cent.	Cum. Per Cent.	Per Cent.	Cum. Per Cent.
Over $\frac{5}{8}$ in.	6.1	6.1	1.1	1.1
$\frac{5}{8}$ + $\frac{1}{2}$ in.	5.1	11.2	2.4	3.5
$\frac{1}{2}$ in. -10 mesh.	24.0	35.2	16.6	20.1
10- 20 mesh.	22.2	57.4	26.2	46.3
20- 30 mesh.	8.0	65.4	10.2	56.5
30- 40 mesh.	5.2	70.6	7.6	64.1
40- 60 mesh.	6.4	77.0	9.8	73.9
60- 80 mesh.	1.2	78.2	1.2	75.1
80-100 mesh.	2.5	80.7	3.0	78.1
100-150 mesh.	2.2	82.9	3.9	82.0
150-200 mesh.	4.2	87.1	4.4	86.4
Below 200 mesh.	12.9	100.0	13.6	100.0
	100.0	.....	100.0	

Crushing efficiency is increased by coarse crushing in "kominuters," both in "kominuters" themselves and in Chilean mills after roasting.

The finer the crushing, the greater the dust losses in the roasters. If too fine, there is a tendency for the hot ore to "run" through the roasters.

The coarser the crushing, the harder it is to roast the mechanically occluded sulphides. The ore may appear to be well roasted when too coarse, but, after regrinding, will fill the solutions with soluble sulphides, which increase the consumption of cyanide. The coarse ore itself does not seem to entail a high residue, but the bad effect upon the solution tends to hinder extraction, unless the plant is very flexible.

The tendency for general efficiency is toward finer crushing for the more basic ores than for the siliceous. This is roughly adjusted by finer screening before the ore enters the "kominuters" and by using the mills with the newest screens. The average should be not more than 30 per cent. coarser than 10 mesh.

THE ROASTING FURNACES

The roasting furnaces used are the Edwards Duplex, 54 rabble, supplied by Stearns-Rogers Mfg. Co. The length is 115 ft. (35 m.); width, 13 ft. (3.9 m.); live roasting area, 1495 sq. ft. (138.8 sq. m.); coolers, 44 ft. (13.4 m.) long and 13 ft. (3.9 m.) wide, with an area of

572 sq. ft. (50.4 sq. m.). There are three fire boxes for each roaster. The temperature of the ore at the discharge point of the roasters is about 485° C.; at the discharge point of the coolers, about 278° C. The temperature depends on tonnage, air temperature and the rate of rabbling. Trials were made on rabble speeds from 1½ r.p.m. up, and the most efficient cooling was at a rabble speed of 6 r.p.m.

Details of the Rabbles

The spindles, rabbles and teeth are made of cast iron by a local foundry. The consumption of teeth is 0.1637 lb. per ton of ore; of rabble arms, 0.0684 lb. per ton of ore, and of spindles, 0.0265 lb. per ton of ore.

Inside the roaster, all rabble arms are water-cooled, the water being pumped from Fountain Creek, just below the mill, to a storage tank on the hill above the roasters. After passing through the rabbles, it is run over a cooling tower and pumped back to the storage tank. The temperature of the water going into rabbles is 25° C. to 34° C., depending upon the temperature of air, the wind, and the tonnage in roasters. Its temperature on leaving the rabbles varies from about 45° C. to 64° C. The water used per roaster per minute varies from 90 to 115 gal. depending upon the condition of the rabbles and the rate of feed.

There are 27 pairs of rabbles in each roaster and 11 pairs in the cooler. In the roasters they travel 3 r.p.m. and in the coolers, 6 r.p.m.

The hearth is sloped from feed to discharge end, ½ in. to the foot (4.17 cm. to the meter), which is sufficient to cause the ore to move forward under the action of the revolving rabbles. For a given rate of feed, the slower the rabble speed the greater the depth of ore. The greater the rabble speed, the less tendency there is to burn, or "ball" the ore under excessive heat.

The average time of passage of the ore through the roasters is 6 hr. From 13 to 17 hp. is required for each roaster and cooler, depending on the feed and the speed of the rabbles.

The roasted ore falls from the cooling hearth through a choke feeder onto a 315-ft. (96 m.) reciprocating drag conveyor. The sheet-iron fins are 34 in. (86.36 cm.) long by 8 in. (20.32 cm.) deep. An average of 16¼ hp. is required to operate it.

The roasters are shut down the first of every month to allow repairs to be made on this drag. The pins that hold the fins are subject to great wear near the discharge end where water is sprayed on the ore before it falls on a rubber conveying belt. This belt is made of specially vulcanized rubber (Diamond Rubber Co.) to withstand the heat and moisture. The ore is at about 90° C. when it falls on this belt and contains 2 per cent. moisture. The contained heat serves, unaided, to warm the cyanide building throughout the year. It has, also, the un-

fortunate effect of warming the cyanide solution in which the ore is crushed, thus putting large quantities of calcium sulphate into solution.

Coal Used for Roasting

The coal is Colorado Springs lignite, supplied by the Pikes Peak Cons. Fuel Co. from their mines 6 miles north of the city. The average analysis is as follows: Water, 20.2; volatile, 54.65; fixed carbon, 19.75; ash, 5.1; sulphur, 0.30; average heating capacity, as mined, 8700 B.t.u. For class A ore, 249 lb. of coal per ton of ore is required for roasting, while for class B ore, 347 lb. is needed. The fire-box is that of the Western Fire-Box Co., a semi-gas producer, requiring the use of live steam; 12 per cent. additional coal is used to generate this steam. The capacity per roaster ranges, for class A ores, from 125 to 150 tons per 24 hr., and for class B ores, from 80 to 100 tons per 24 hours.

Flue Losses

Extensive stack tests were made in 1909 to determine the flue losses. The method was the use of the Pitot tube for measuring velocities and employing bags for collecting the dust. The volume of flue gases per roaster was 208,000 cu. ft. per min. At the time of the first tests, the revolving cooler was in use and the stack loss amounted to 13.2 c. per ton on 1-oz. ore. After changing to the present coolers, the dust loss was 3 to 4 c. per ton of 1-oz. ore. The amount of flue-dust collected was formerly from 0.7 to 0.9 per cent. by weight and carried a value 32 per cent. higher than the ore. It is now 0.4 per cent. by weight and carries a value 20 per cent. higher than the ore. The open cooler and more careful feeding and discharging has made this difference.

Conditions of Roasting

The temperature, as indicated by Brown indicating pyrometers, is as follows:

Class A ore—800° to 870° C. in the center of the arch, 8 ft. above No. 1 fire-box and in the flow of heat; 800° to 850° C. 8 ft. above No. 2 fire-box.

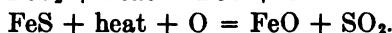
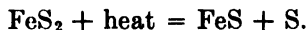
Class B ore—850° to 900° C. above No. 1 fire-box; 850° to 870° C. above No. 2 fire-box.

In roasting all ores, No. 3 fire-box keeps the ore at a red heat up to the point of discharge. The hotter the ore is kept here, the less tendency there is for the sand of class B ore to "set" in the leaching tanks. Class A ores show no such tendency within the present treatment conditions. Nevertheless, they will do so under other conditions of classification and filling.

A few practical points in the operation of the roasters are worthy of notice. The draft should be kept up to about 0.2 in. of water at all times to allow a free escape of the gases and consequently a more oxidizing atmosphere. The flames from the fire-boxes must be given an excess of air to keep them from being smoky, as their reducing effect then is quite strong.

CHEMICAL REACTIONS IN ROASTING

Siliceous Ores



FeSO_4 is found when roasting at low temperatures, but at high temperatures this decomposes into FeO and SO_3 or $\text{SO}_2 + \text{O}$.

Basic Ores

In the roasting of calcareous ores containing metallic sulphides, if sufficient sulphur be present the lime is converted almost quantitatively into CaSO_4 . The behavior of CaSO_4 , when heated in the presence of CO and C , has been investigated by H. O. Hofman and W. Mostowitsch.¹ The chemical reactions and temperatures stated herein are quite largely taken from their reports. They are given, as they appear to fit the class B ores as roasted.

The reduction of CaSO_4 by CO is indicated in the equation $\text{CaSO}_4 + 4\text{CO} = \text{CaS} + 4\text{CO}_2$. The reaction takes place without any loss of sulphur. Very little reaction takes place unless the temperature is above 680°C . Between 750° and 850°C . the action is quite rapid and is completed at 900°C .

The reduction of CaSO_4 by carbon is indicated in the equations $\text{CaSO}_4 + 4\text{C} = \text{CaS} + 4\text{CO}$, and $\text{CaSO}_4 + 2\text{C} = \text{CaS} + 2\text{CO}_2$. The action begins fairly well at 700°C . and finishes at 1000°C ., proceeding most rapidly between 800° and 900°C . At about 800°C ., $\text{CaSO}_4 + 2\text{C} = \text{CaS} + 2\text{CO}_2$; above 800°C ., $\text{CaSO}_4 + 4\text{C} = \text{CaS} + 4\text{CO}$.

It was found that CO acted more readily and effectively than carbon alone, both beginning and finishing at lower temperatures. It is probable that the gases CH_4 , C_2H_6 , and H would act similarly in the reduction of CaSO_4 , since they are effective with Na_2SO_4 .

CaS , if roasted in pure, dry air, does not all revert to CaSO_4 , but forms a product of about 76 per cent. CaSO_4 and 24 per cent. CaO , with a loss of approximately 32 per cent. S . This loss of S is accounted for by the interaction of CaSO_4 and CaS , according to the reaction $3\text{CaSO}_4 + \text{CaS} = 4\text{CaO} + 4\text{SO}_2$.

¹ *Trans.* (1910), 41, 763.

The complete elimination of sulphur at this point is probably prevented by the failure of intimate contact between the CaS and CaSO_4 . Action between CaSO_4 and CaS takes place in a neutral or oxidizing atmosphere, but not in a reducing one.

When heating pure CaSO_4 in the presence of oxygen it loses its combined water at 900°C . and begins to decompose at 1250° to 1300°C . In the presence of SiO_2 it starts to decompose and gives off SO_2 at 1000°C . and decomposition is completed at 1250° to 1300°C . The action is shown in the equation $\text{CaSO}_4 + \text{SiO}_2 = \text{CaSiO}_3 + \text{SO}_2 + \text{O}$.

An interesting equation is $\text{CaS} + \text{FeSO}_4 = \text{CaSO}_4 + \text{FeS}$. It takes place at a low temperature.

ROASTING FOR CYANIDE TREATMENT

In roasting for cyanide treatment, both sulphates and soluble sulphides are deleterious. Soluble sulphides are active cyanicides and attack zinc freely. They are active reducing agents and under certain conditions can completely eliminate all oxygen from the solutions.

Though precipitating gold to an appreciable extent only in acid solution, when the solution percolating a leaching charge becomes de-oxidized by an excess of soluble sulphide, either gold is precipitated or the undissolved gold is so coated as to render further dissolution so extremely slow that to obtain a commercially good residue is impossible. In agitating slimes, especially without air, a similar condition is brought about.

It is interesting to note that if such a residue is completely dried or thoroughly treated with a solution of permanganate of potash or other effective soluble oxidizer, then subjected to cyanide treatment, the normal residue is obtained rapidly.

Acid sulphates act as virulent cyanicides if not quickly neutralized. Calcium sulphate, formed either in the roasters or by reaction of soluble sulphates in the ore on meeting the lime in solution, is decidedly deleterious. The hot ore warms the crushing solution. This becomes saturated with calcium sulphate which precipitates as the solution cools. These crystals fill pipes, launders and Dorr thickeners, render filter mats and clarifying mats impermeable, coat Merrill filters, frames and cloths and form a deposit on the zinc and zinc boxes. In class A ores these troubles are comparatively unimportant, although considerable lime is required to neutralize the solutions, whereas class B ores often require none.

Formation of Soluble Calcium Sulphate

We believe that the chief formation of soluble calcium sulphate, with class B ores, occurs in the roasters. It will be noted in the roaster equations quoted that, somewhere above 870°C ., the final molecule of water

is driven out of the calcium sulphate; it then becomes practically insoluble in working solutions and does not form a cement in the sand tanks.

For illustration, a ton of deposited calcium sulphate crystals and slime, if fed slowly or rapidly into the Chilean mills, forms a band of cement sand in the leaching vats and redeposits throughout the plant. If, however, 10 tons of this material is fed into the "kominuters" and thence through the roasters, meeting a heat of 870° C. or higher, it cannot be noticed in the cyanide plant.

It is commercially possible to roast ores so that they may be treated with the ease of a free-cyaniding raw ore; this is what we call an "over-roast." Such ore can be extracted to a finished residue in a good standard cyanide plant. Chemical consumption is held at a minimum. Standard classification is sufficient and no change of solution is necessary. Dissolution is rapid and reaches a definite end point. But the roast is decidedly more expensive, and the final residue much richer than that now obtained.

Table 2 shows the value of typical sand residues from class B ore, first that from an over-roasted ore, and second, an average sand residue such as is now obtained.

TABLE 2.—*Value of Sand Residues from Class B Ore*

Screen Mesh	Over-roasted Ore		Average Residue	
	Weight, Per Cent.	Gold, Ounce	Weight, Per Cent.	Gold, Ounce
Over 20.....	.....	.....	1	0.01
20-30.....	4	0.03	5	0.01
30-40.....	14	0.04	15	0.01
40-60.....	23	0.05	35	0.02
60-80.....	14	0.04	} 16	0.02
80-100.....	16	0.05		
100-150.....	11	0.06	12	0.02
150-200.....	10	0.09	13	0.02
Below 200.....	8	0.12	3	0.04
	100	0.0571	100	0.0185

The slime residues show even a greater difference in gold content due to over-roasting, the difference being more marked in class B than class A ores.

Having found that a better residue could be obtained by a cheaper and, as indicated by ordinary sulphur analyses, a less complete roast, it was decided to attempt a more efficient treatment by more delicate roasting. This required a quick method of chemical testing and the

use of pyrometers to help regulate the temperature of each roaster continuously.

Chemical tests were employed for governing the roast. For class A ores a simple analysis of total, soluble, and insoluble sulphur is a sufficient guide to an experienced fireman, which, with the temperature and appearance of the roaster, soon enables him to regulate his fires. The feed is changed only by the foremen.

RAPID METHODS OF ANALYSIS FOR SULPHUR IN ORES

Total Sulphur in Roasted Ore

Weigh out 1.373 gm. ore, add about 11 drops of a saturated solution of KClO_3 in HNO_3 , and two or three drops of HCl . Take down to complete dryness to render SiO_2 insoluble, but do not make too hot or H_2SO_4 will be driven off. Cool, add 5 c.c. HCl , boil off excess, add about 25 c.c. hot H_2O , and boil.

Remove from heat, make alkaline with smallest necessary amount of 1 : 1 NH_4OH to precipitate iron and leave supernatant liquid clear. Filter and wash twice with hot water. Put filter paper and contents back into same beaker, break filter with 10 to 20 c.c. hot water, and add just enough HCl to dissolve hydrates; put on hot plate a few minutes till solution is effected, then reprecipitate as before with smallest necessary amount of 1 : 1 NH_4OH , filter and wash into same beaker containing first filtrate. Make filtrate acid with HCl , boil, add a few drops HCl (to prevent boiling over when BaCl_2 is added) and then an excess of boiling BaCl_2 ; settle, cool, filter on best double filter paper, wash twice with water, once with 1 : 1 HCl , then 10 times with water; ignite and weigh BaSO_4 .

HCl-soluble Sulphur in Roasted Ore

Weigh out 1.373 gm. ore, add about 30 c.c. N/10 HCl solution, boil 10 min., filter, and wash well with hot water. Refilter through a new double paper and wash well. Boil, add a few drops HCl and an excess hot BaCl_2 solution. Settle, cool, filter on double paper, wash, ignite and weigh.

The insoluble sulphur is obtained by difference.

Na_2CO_3 -soluble Sulphur in Roasted Ore

This is run as a check on the HCl method. It gives an insoluble sulphur that is usually about 0.03 per cent. higher than the HCl , the notable exceptions being a bad roast on a lime bed, when it may go 0.05 to 0.10 per cent. higher.

Weigh 1.373 gm. ore, boil 10 min. with 30 c.c. N/ Na_2CO_3 solution, filter and wash well with hot water. Add about 4 c.c. HCl to filtrate, or till acid, boil out CO_2 , make just alkaline with a few drops 1 : 1 NH_4OH and boil out NH_3 . Filter and wash with hot H_2O , acidify filtrate with HCl , boil, add a few drops HCl and an excess of hot BaCl_2 solution, settle, cool, filter on double paper, wash, ignite, and weigh.

Class B ores cannot be roasted correctly even approximately by reliance upon visual judgment. The same soluble and insoluble sulphur analyses must be made, but these do not distinguish between the soluble

CaSO_4 and CaS , the first of which is harmful principally in setting the sand tanks, while the second interferes greatly with the extraction.

The usual analyses, therefore, combined with our custom of getting only one report a day, proved too slow to prevent bad roasts, and it was found advisable to develop a quick reliable test for soluble sulphides, by means of which a check could be kept on each individual roaster. Arlo C. Greenawalt was detailed to devote his entire time to developing a method. After trial of all available text-book methods, he decided upon the following as the best practical method.

Rapid Determination of Soluble Sulphides

Weigh 15 gm. roasted ore crushed through 80 mesh into a 150-c.c. casserole. Pour onto it 50 c.c. boiling 5-lb. KCN solution, containing 12 lb. NaOH per ton (0.6 per cent.). Boil for 15 min., then filter by aid of a vacuum into a 100-c.c. graduated cylinder. Wash well with hot water and bring volume of filtrate up to 50 c.c. Mix contents thoroughly by inverting the cylinder several times. Extract two samples of 10 c.c. each. To one sample add an excess of $\text{KAg}(\text{CN})_2$ solution and about 1 gm. dry CaO . To the second sample add about 2 gm. dry PbCO_3 . Heat solutions to boiling, filter and wash well with hot H_2O . Add $\frac{1}{2}$ c.c. of 1 per cent. KI solution to each filtrate, and titrate with AgNO_3 (13.038 gm. per liter). Subtract the amount of AgNO_3 used with the solution to which PbCO_3 was added, from the amount used with the solution to which $\text{KAg}(\text{CN})_2$ was added. To obtain percentage of soluble sulphides, multiply this difference by 0.16415.

Explanations and Precautions

The above method is based on the fact that when $\text{KAg}(\text{CN})_2$ is added to a solution containing alkaline sulphides, a definite amount of free KCN is formed for every atom of silver that combines with the soluble sulphur to form Ag_2S , the equation being $2\text{KAg}(\text{CN})_2 + \text{K}_2\text{S} = \text{Ag}_2\text{S} + 4\text{KCN}$.

It is necessary that the solution of KCN be boiling before adding to the ore, as oxidation of the sulphides will take place in a cold solution. NaOH is added to make the solution alkaline, as results cannot be obtained in acid solution.

A weak KCN solution should be used, as it will take the sulphides into solution readily, and will require a minimum amount of AgNO_3 for titration.

When $\text{KAg}(\text{CN})_2$ is added to the solution, the precipitation of Ag_2S is usually incomplete and the precipitate seems to be partly colloidal. The CaO is added to coagulate the precipitate, and boiling insures complete precipitation.

The wash water should be hot in order to prevent oxidation of the sulphides to sulphates, which occurs if solutions are allowed to cool.

The addition of KI before titration corrects errors due to the presence of caustic alkalies.

Titration of solution to which PbCO_3 was added gives the original cyanide present. Titration of solution to which $\text{KAg}(\text{CN})_2$ was added gives the original cyanide plus the free cyanide that was formed. The difference between the two, or the free cyanide, is directly proportional to the amount of soluble sulphides present in the solution.

The calculation of the value of 1 c.c. AgNO_3 (13.038 gm. per liter), in terms of percentage of soluble sulphides, is as follows:

$$\text{KCN} = 65.11. \quad \text{KCNS} = 97.18. \quad \text{S} = 32.07.$$

$$1 \text{ c.c. } \text{AgNO}_3 = 0.01 \text{ gm. KCN.}$$

$$65.11 \div 97.18 = 0.01 \div x$$

$$x = 0.01492 \text{ gm. KCNS per c.c. } \text{AgNO}_3.$$

$$32.07 \div 97.18 = x \div 0.01492$$

$$x = 0.004924 \text{ gm. sulphur per c.c. } \text{AgNO}_3.$$

$$\frac{0.004924 \times 100}{15} = 0.03283 = \text{per cent. sulphides.}$$

With 15 gm. ore taken for analysis, $0.03283 \times 5 = 0.16415 = \text{per cent. soluble sulphides per c.c. of } \text{AgNO}_3$, as titration took place in 10 c.c. and the total volume was 50 c.c.

If the volume should happen to be larger than 50 c.c., say 57 c.c., the factor is obtained thus: $5.7 \times 0.03283 = 0.16696 = \text{per cent. soluble sulphides per c.c. } \text{AgNO}_3$. This method can be run through with nine roaster samples in about $1\frac{1}{2}$ hr., and, while not absolutely accurate, is the best we have found, and is sufficient for controlling the feeds to the roasters, when the temperatures, as noted above, are maintained.

The limits of insoluble sulphur are: Class A, 0.10 per cent.; class B, 0.15 per cent. The limits of soluble sulphide are: Class A, 0.10 per cent.; class B, 0.15 per cent.

Experience has shown that class B ores give good residues with higher total and insoluble sulphur and soluble sulphide, than class A. The chemical reasons for this are still obscure, but it is possible that the interaction between the sulphates and sulphides in the roasters, as noted above, gives a larger amount of each as a secondary reaction, and these then do not have so deleterious an effect in the treatment.

OPERATING CONDITIONS IN THE CYANIDE PLANT

The decision to adopt the above-mentioned more efficient and more delicate treatment necessitated a more carefully planned and flexible cyanide plant, specially arranged to cope with the ore thus roasted. The following are the more important operating factors:

1. Substitution of blanket concentration of gold for plate amalgamation.
2. Elimination of colloids, so far as possible, from the part of the ore to be leached.

3. Ability to change solutions quickly on both sands and slimes.
4. Filling the leaching tanks with a semi-dewatered product.
5. Aeration of slimes soon after classification.
6. More time of agitation.
7. Use of the Crowe vacuum system of precipitation.

1. Amalgamation plates are decidedly more sensitive to unfinished roasting than is cyanide solution. The coarse gold is coated with an alloy which dissolves slowly and is not wetted by quicksilver.

Blankets catch this gold effectively and the particles amalgamate readily when the surface is abraded. The amalgamation treatment includes a small arastra, followed by a grinding pan with universal joint between yoke and muller, and followed by another arastra. The tails are re-blanketed before passing into the main mill flow and the final concentrate is amalgamated in a barrel in strong cyanide solution.

2. The elimination of colloids from the sands is perhaps the most important detail of all. Unless the sands leach exceedingly fast, a "slip-up" in one roaster will cause the complete de-oxidation of solution before it reaches the filter bottom, causing a rich residue. If the leaching charge channels perceptibly, the same condition develops in patches. Moreover, in the class B ores there is a marked tendency for the sands to set while leaching. Freedom from colloids distinctly minimizes such tendency.

It was not until 1915 that the more basic ores began to arrive in large quantities and changes in treatment became imperative. There was no available floor space for step classification, and the clumsiness and the expense of a series of cones and pumps were not attractive. The problem was solved by the installation of the Dorr bowl classifier, which makes a separation as efficient, on this class of work, as any ordinary three-stage classification, uses less floor space than was necessary before, requires the minimum of attention, additional solution, and power, and its cost for installation and operation are less.

Our plant requirements are: For the slime plant, all material must pass through 100 mesh and not over 12 per cent. remain on 200. For the leaching plant, the sands must be free from colloids.

Between these limits, the feed to the classifiers may vary from the product of two Chilean mills—400 tons of ore—to six Chilean mills—1200 tons—without any classifier adjustments. This is useful, since we control our power peak at the Chilean mills.

3. Change of solution must be made quickly to allow a good margin between an over-roast and an under-roast. On the sands, it is done by the back flow or wash solution in the classifiers.

The slimes flow to a 50-ft., connected-type Dorr tray thickener. The compartments are shallow and the settling capacity always ample. Under these conditions, the slime is quickly passed through as thickened

5. Aeration of slimes immediately after classification is very effective—probably such aeration almost instantly gets rid of the unstable soluble sulphides. We attempt to do it fairly fast without additional agitation storage. Possibly, if room permitted, an aerating agitator between classifiers and first settler would be more effective.

6. It is found that a roast giving the lowest residue also gives a slow-treating slime. Therefore excessive agitation is a good safety insurance, and the additional agitation is obtained in a 37 by 23-ft. Dorr agitator, at a cost of 4 mills per ton.



FIG. 2.—DORR DUPLEX CLASSIFIER WITH 6-FT. BOWL.

7. The precipitation of solutions from moderately roasted ores, especially of the more basic type, has been distinctly difficult. A marked improvement in effectiveness and cost has been made by the installation of the Crowe vacuum system of precipitation.

CONCLUSIONS

There is room for argument regarding the relative efficiency of treating roasted ores in an all-sliming cyanide plant, or in a combination slime and leaching plant. The all-sliming plant is probably less costly to install, and it reduces the number of metallurgical problems. This ore,

however, after roasting, does not require finer grinding than 20 mesh. Further grinding, even in normal times, costs more than the extra recovery attained.

The slimes from a roasted ore have small adhesive qualities and are incapable of sustaining much sand. This limits the type of cyanide apparatus available, unless the all-sliming process is carried far beyond the economical crushing limit.

Undoubtedly, under local conditions, the residues can be dumped far more economically from a combination slime and leaching plant than from an all-slime process.

The ore is high grade and requires a high-strength cyanide solution, thus limiting the effectiveness of the countercurrent decantation system, although this system is partially used with good effect in the present slime plant, both as a help in extraction and in washing the values from the filter cakes.

If the sands are sufficiently eliminated from the slime product, the latter is an ideal filtering material; but, even so, the filter department is more expensive to operate, requires more care and more wash solution per ton of ore, and loses more cyanide and gold mechanically than the sand plant.

The deciding feature between the two types of plant lies in the possibility of consistent efficient classification. With poor classification, the advantages lie with the all-sliming process. With good classification, the balance swings decidedly to the combination plant.

The authors were asked to write upon the subject of roasting sulpho-telluride ores for cyaniding. The roasting is so interdependent upon the mechanical and chemical details of the cyanide plant that the former is unintelligible without knowledge of the interlocking features of the latter. This is our excuse for the length of detail in this paper.

DISCUSSION OF THIS PAPER IS INVITED. It should preferably be presented in person at the Colorado meeting, September, 1918, when an abstract of the paper will be read. If this is impossible, then discussion in writing may be sent to the Editor, American Institute of Mining Engineers, 29 West 39th Street, New York, N. Y., for presentation by the Secretary or other representative of its author. Unless special arrangement is made, the discussion of this paper will close Oct. 1, 1918. Any discussion offered thereafter should preferably be in the form of a new paper.

Effect of Oxygen upon the Precipitation of Metals from Cyanide Solutions

• BY THOMAS B. CROWE, E. M.,* VICTOR, COLO.

(Colorado Meeting, September, 1918)

MUCH has been written upon the precipitation of metals from cyanide solution by zinc. We often read of the many factors that influence precipitation, such as zinc surface, purity of zinc, percentage of lead, temperature of solutions, strength of solutions in cyanide or alkali, etc. Little do we hear, however, of the part that oxygen plays in precipitation.

Caldecott¹ says: "As the dissolving of gold is essentially an oxidation process, so its precipitation is one of reduction." All who have studied or worked with cyanide solutions will agree that Caldecott's statement is true. In the cyanide work in the mills of the Portland Gold Mining Co., we have always found oxygen to be the greatest enemy to precipitation.

OXYGEN ANTAGONISTIC TO GOOD PRECIPITATION

A few years ago, while making some experiments on the effect of pressure upon the dissolving rate of gold from our ores, to prove a point, I made some bottle tests under vacuum. The results were surprising, and showed that under vacuum practically no gold dissolved, which confirmed my belief that Elsner's equation was true and also led me to investigate the amount of dissolved air carried by solutions at atmospheric pressure.

The experiment consisted in partly filling an acid-bottle with mill-solution and connecting it by a rubber hose to a vacuum pump. When the vacuum was suddenly applied, a cloud composed of thousands of small air bubbles rose out of the solution, showing qualitatively the amount of dissolved air that was contained in the solution, and also proving that the relief of atmospheric pressure on the solution permitted this dissolved air to escape.

In studying literature on the subject, we find Henry's law—"The amount of gas dissolved by a liquid is proportional to the pressure to which the gas is subjected."

* Mill Superintendent, Portland Gold Mining Co.

¹ W. A. Caldecott: Chemistry of Banket Ore Treatment, 389; in *A Text-book of Rand Metallurgical Practice* by Ralph Stokes and others. London, Charles Griffin & Co., Ltd., 1912.

We find that at atmospheric pressure, water dissolves from 2 to 4 per cent. of air by volume.

We also find that when air is dissolved by water, owing to the different coefficients of absorption of oxygen and nitrogen, the absorbed air has the composition of about 35 per cent. oxygen and 65 per cent. nitrogen, while ordinary atmospheric air is about 21 per cent. oxygen and 79 per cent. nitrogen. Mill solutions, then, contain not atmospheric air, but a per-oxidized atmospheric air, which is very good for oxidizing but very injurious to the reduction process of precipitation.

In the early days of zinc-dust precipitation, the dust was sprinkled over the top of a tank of solution while under agitation; large quantities of zinc were used and the solution tailing was far from what was desired.

Later Merrill's improved method came out, the principal characteristic of which was the exclusion of air from contact with the precipitant and precipitate during precipitation. Merrill's method was a big improvement over the old scheme, allowing a material reduction in the quantity of zinc used, with much lower barren solutions, and showed very plainly the effect of oxygen in former work.

Having had the sad experience of allowing free air to pass with my solution through the precipitation press, and knowing that Merrill's process had been an improvement over the old open-tank process, I naturally reasoned that the removal of the dissolved air from solution would be the means of further benefiting precipitation, providing a vacuum could be practically applied to solution, prior to, or during precipitation.

Laboratory tests on the application of a vacuum to solution before the addition of zinc-dust confirmed my theory. Large tests were tried, apparatus was designed that would continuously apply a vacuum to solution during its flow to the precipitation presses, and gradually the vacuum system of precipitation worked its way into our mills, with the result that the zinc consumption has been cut in half, which fact is especially gratifying to us during the war period with its prevailing high prices.

EFFECT OF VACUUM PRECIPITATION ON CONSUMPTION OF CYANIDE

Having been successful in reducing the amount of zinc used, and as the price of cyanide kept soaring, we decided to try to make a reduction in cyanide consumption.

A thorough scrutiny of our former work revealed the fact that, for dissolution purposes on our particular ore, the cyanide solution strength was much higher than was necessary, having been kept high for the sake of good precipitation. In fact, the solution strengths in our mill had been reversed—the strongest solution was the barren; and this being used as a wash on the filters, occasioned high cyanide consumption. The

high strength of the barren solution was caused by the necessity of adding lump cyanide at the head of the precipitation process to insure low-grade solutions to be used in washing.

With the installation of our vacuum system, we found that perfect precipitation could be maintained without the addition of lump cyanide, and today our mills are running with the highest solution strength in the agitators, and not in the barren tank. This, together with a generally lower solution strength in all parts of the mill, has allowed a material reduction of cyanide consumption.

Table 1 will give an idea of the amount of cyanide and zinc used before and after the installation of the vacuum precipitation.

TABLE 1.—*Comparison of Ordinary and Vacuum Precipitation Systems*

	Tons of Solution Precipitated	Pounds NaCN per Ton Ore	Pounds Zn per Ton Ore	Pounds Zn per Ton Sol.
12 months, Year 1915.....	503,819	0.331	0.407	0.174
12 months, Year 1916.....	536,455	0.320	0.369	0.150
6 months, Year 1917.....	249,988	0.175	0.191	0.084

Years 1915 and 1916, ordinary zinc-dust precipitation. Year 1917, vacuum precipitation.

OPPOSING ACTION OF OXYGEN AND HYDROGEN

How often have we found, when working with zinc shavings, that the only remedy for poor precipitation, excepting the addition of lump cyanide to the head of the box (which has its limitations), is a cleanup or redressing of the box.

Assays of the effluents from the different compartments of a box during a period of good precipitation generally reveal the fact that each compartment in the series is doing some work, there being a gradual reduction of the value of the solution as it progresses from compartment to compartment.

A similar series of assays taken during a period when precipitation is only fair, the box being inclined to give erratic results, shows that the first compartments of the series are doing very little work, the burden consequently being thrown on those compartments lower in the series. A third series of assays, taken when precipitation is bad, generally shows that not only is no precipitation occurring in the first compartments, but that the first compartment is giving up its gold, the values being carried to the lower compartments and sometimes entirely out of the box. Decreasing the rate of flow of solution through the box sometimes helps this condition and increasing the cyanide strength also gives temporary relief, but a redressing of the box seems to be the only real remedy.

During precipitation, two opposing forces are continually working: first, a precipitating force; second, a dissolving force. The precipitating

force is a reducing action and is caused by the dissolving of the zinc, which creates an electro-motive force and evolves hydrogen. Nascent hydrogen seems to be the active agent that causes precipitation. The second, or dissolving force, is an oxidizing action, its strength being a function of the amount of oxygen carried by the solution.

Reducing agent hydrogen and oxidizing agent oxygen are decided enemies, and cannot live together in the same solution. When nascent hydrogen, caused by the dissolving of zinc in cyanide solution, is generated, its first work is that of combating its enemy, oxygen, combining with it and getting it out of the way. After this is done, it then takes up the rôle of precipitation and plays its part.

When large quantities of zinc are dissolved and plenty of hydrogen is evolved, as is the case when lump cyanide is added to the head of the box, the effect of oxygen becomes insignificant, but when the cyanide solution strength is low and very little zinc is dissolved, then the oxygen in solution may gain supremacy over the evolved hydrogen and result in poor precipitation or, in extreme cases, dissolution of precipitated gold. Especially is this true when the zinc has been in use for long periods and the first compartments are rich in gold and poor in zinc. A freshly dressed box presents more zinc surface and, in a cyanide solution of a given strength, has a certain power to reduce and precipitate, this power becoming less and less as it does its work. This work consists of a very small job of precipitating and a very large job of counteracting the effects of oxygen contained in the air dissolved in solution.

Why then allow this enemy of precipitation to pass with the solution into the zinc press or box, when it can so easily be removed by the application of a vacuum during its flow?

When the air in solution is removed prior to precipitation and the deoxidized solution is run or pumped through the precipitating system, only the burden of precipitating is put upon the zinc and we find, when this is done, that a very weak electro-motive force is sufficient to effect precipitation, which means that one can operate with both weaker cyanide-solution strength and with smaller amounts of zinc, producing a higher-grade precipitate with less cost for cutting down and refining.

DISCUSSION OF THIS PAPER IS INVITED. It should preferably be presented in person at the Colorado meeting, September, 1918, when an abstract of the paper will be read. If this is impossible, then discussion in writing may be sent to the Editor, American Institute of Mining Engineers, 29 West 39th Street, New York, N. Y., for presentation by the Secretary or other representative of its author. Unless special arrangement is made, the discussion of this paper will close Oct. 1, 1918. Any discussion offered thereafter should preferably be in the form of a new paper.

Fine-grinding Cyanide Plant of Barnes-King Development Co.

BY J. H. MCCORMICK,* MARYSVILLE, MONT.

(Colorado Meeting, September, 1918)

THIS plant, near Marysville, Mont., was planned to treat the ore from the Piegan and Gloster mines, the latter being one of the early and famous producers of the Marysville district. When the mill was closed in 1888, treatment consisted of stamp milling, followed by pans and settlers for pan amalgamation. The extraction was evidently poor, because, a few years later, thousands of tons of tailings were re-treated by the ranchers in the valley below the mill, by the then new cyanide process, and gave a handsome profit.

In 1914, the present owners, after laboratory tests and an experimental mill run, decided upon the following treatment: crushing to 40 mesh in cyanide solution, concentration, amalgamation, classification, and cyanidation of sands by leaching, and of slime by agitation and decantation in charges. The ore averaged about \$7 per ton, gold and silver, the ratio of weight being 1 oz. gold to 7.56 oz. silver. The ratio of gold and silver in tailings was 1 oz. Au to 36.6 oz. Ag; the quartz was sharp and sandy, however finely ground, and rather difficult to slime.

The mechanical equipment was a No. 5 Symons gyratory crusher; three 10-ft. Lane slow-speed Chilean mills; one Wilfley roughing and one finishing table; one submerged-type Akins classifier; five 26 by 10-ft. fir leaching tanks; one 24 by 7-ft. Dorr thickener; four 14 by 16-ft. Dorr agitators; four 6-compartment double-row zinc-boxes having compartments 18 in. wide, 18 in. deep, and 34 in. long; Johnson zinc lathe; acid and vacuum filter tanks for treating precipitate; roasting furnace; and Case tilting No. 275 crucible furnace for melting precipitate.

The mill is driven by electric power supplied by the Montana Power Co. at the following rates, per kw.-hr.: 200 to 300 hp., 0.68 c.; 300 to 500 hp., 0.61 c.; 500 to 750 hp., 0.55 c.; plus \$1 per month per installed motor horsepower.

The plant as above described was operated from May, 1915, to the end of the year, when an additional Dorr thickener and a 12 by 12-ft. Portland revolving filter were added, increasing the nominal capacity of 100 tons per 24 hr., but not the percentage of extraction. The combined treatment, at a cost of \$1.48 per ton, saved 90 per cent. of the gold and

*Superintendent, Gloster Mill.

59 per cent. of the silver, of which 78 per cent. was extracted by cyanide, 20 per cent. by amalgamation and 2 per cent. by concentration.

The amalgamation was accomplished in copper launders, attached to the concentrate end of the Wilfley finishing table; concentrates, at a ratio of 1 ton to 510 tons ore, averaged 12 oz. gold and 59 oz. silver per ton, and were leached with cyanide solution for 14 days to an average value of 1.1 oz. gold and 26.75 oz. silver, before being shipped to a smeltery.

It will be noticed that the whole of the crushing was accomplished in two stages—gyratory crusher and Chilean mills—screen analyses of the products being given in Table 1.

TABLE 1.—*Screen Analyses of Chilean Mill Product and Classifier Products*

Mesh	Chilean Mill Product		Sands		Slimes	
	Per Cent.	Cum. Per Cent.	Per Cent.	Cum. Per Cent.	Per Cent.	Cum. Per Cent.
Over 48.....	10.9	10.9	24.2	24.2		
48- 65.....	11.6	22.5	20.9	45.1	2.1	
65-100.....	17.0	39.5	29.2	74.3	11.1	2.1
100-150.....	13.6	53.1	14.0	88.3	12.1	13.2
150-200.....	7.6	60.7	5.5	93.8	74.7	25.3
Below 200.....	39.3	100.0	6.2	100.0	100.0	100.0
	100.0		100.0			

The final products were admirably adapted for the treatment of that particular ore, if the cost of all-slime treatment was to be avoided.

During this period of operation of the plant, the development of the Shannon mine was going forward, with the expectation of beginning to mill Shannon ore by July 1, 1916. The Shannon ore is different in character from that of the Piegan and Gloster mines, the grade being nearly double, with 93 per cent. of the total value in gold.

Since it was advisable to use the one mill for all the ores, an all-slime treatment was adopted, requiring the following changes and additions to existing milling equipment: A standard Dorr duplex classifier, in addition to the Akins classifier, following Chilean mills; two 5 by 16-ft. pebble tube-mills having Komata lining (each driven by 50-hp. motor, short-belt drive) with two standard Dorr duplex classifiers in closed circuit; and two 12-in. bucket elevators in the crushing department. Three of the leaching tanks were converted into thickeners (one into a simple thickener and two into single-tray thickeners); the remaining two leaching tanks were converted into Dorr agitators by increasing their depth to 20 ft; a new Dorr thickener, 29 by 7 ft., was added, and another

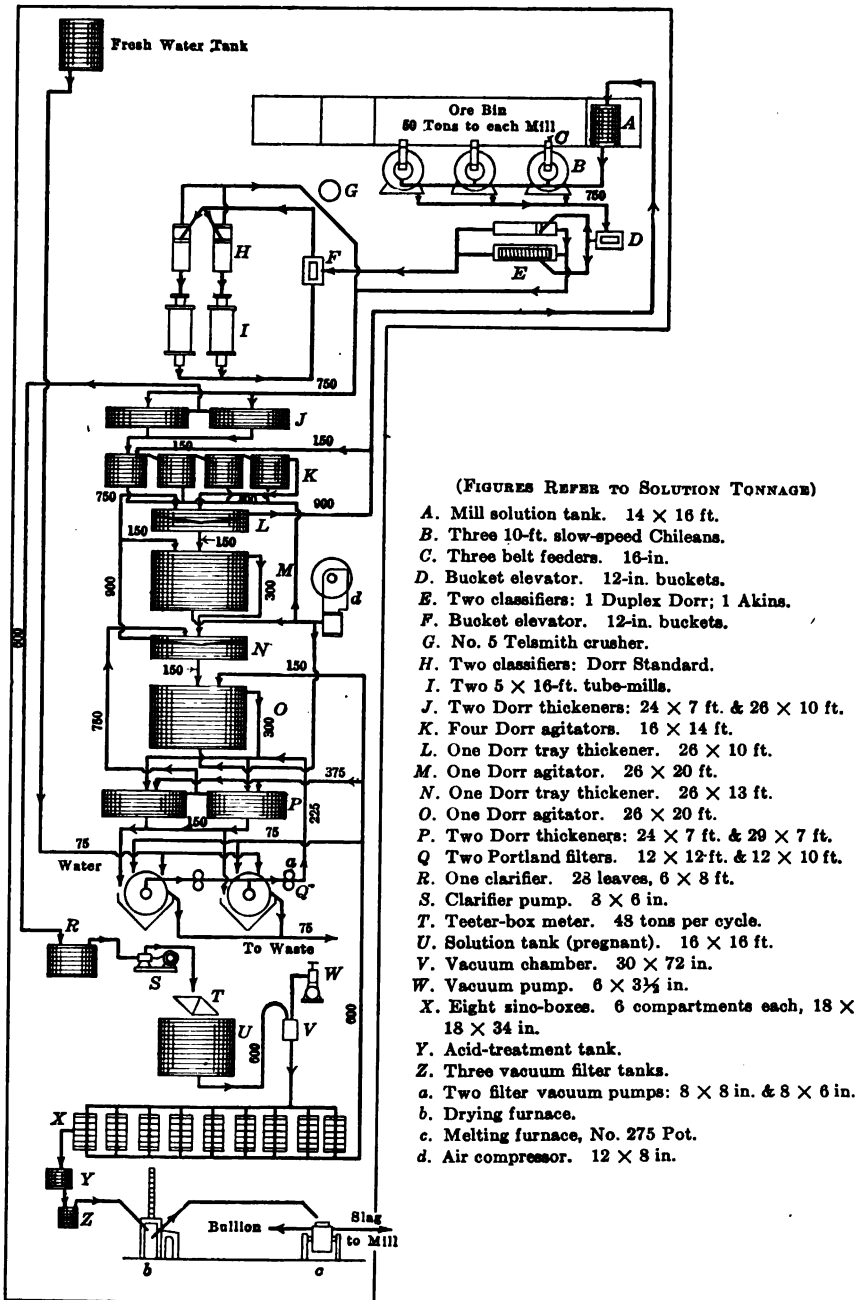


FIG. 1.—FLOW SHEET OF GLOSTER MILL.

Portland revolving filter, 12 by 10 ft., also a set of twenty-eight 6 by 8-ft. clarifying leaves. Zinc-box capacity was doubled.

The remodeled plant went into commission in August, 1916, with a nominal capacity of 150 tons per 24 hr., with 60-hr. treatment; for 10-day periods, over 200 tons per 24 hr. have been treated, with a slight decrease in extraction. Concentration and amalgamation were continued in the fine-grinding plant for a period of six weeks, and were then abandoned, with no loss in total percentage of extraction.

The unusual feature of the plant is the use of slow-speed Chilean mills for crushing the product of coarse breakers. These mills make a remarkable reduction, but leave some fine sand to be slimed in the tube-mills. Repairs are required rather frequently and access to make repairs is difficult, making the mills unpopular with the attendants. Crushing costs,

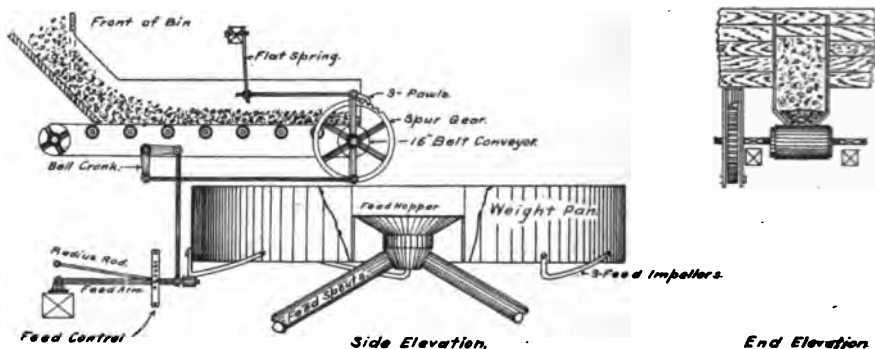


FIG. 2.—AUTOMATIC FEEDING DEVICE FOR LANE MILLS.

however, shown in Tables 4 and 5, compare favorably with other modes of coarse crushing, being, in fact, rather less than those shown by larger plants using ball-mills. An undesirable feature of these mills in a slime plant is that their product is too uniformly fine for regrinding in a pebble-mill without undue consumption of pebbles.

Treatment is now as follows (Fig. 1): crushed ore from the two mines, approximately 100 tons of Shannon and 50 tons of Gloster per day, carrying 6 and 8 per cent. moisture respectively, go into the same receiving bin, from which it is fed to the Chilean mills by belt-conveyor feeders, actuated by cams on the mills, which automatically keep a fairly uniform depth of ore between the tires and the dies (Fig. 2). To each ton of ore fed, 4.3 tons cyanide solution, 0.0375 per cent. strength, and 10 to 12 lb. of lime are added at the feed hoppers. The average rate of crushing in the Chilean mills is 2.69 tons per hour per mill, screen analysis of the feed and discharge being shown in Table 2.

TABLE 2.—*Screen Analysis of Chilean Feed and Discharge, and of Final Product*

Size	Chilean Mill Feed		Chilean Mill Discharge		Classifier Underflow to Tube-mills		Classifier Overflow	
	%	Cum. %	%	Cum. %	%	Cum. %	%	Cum. %
Over 3 in.	0.4	0.4						
3 in.-2 in.	2.9	3.3						
2 in.-1½ in. ...	7.5	10.8						
1½ in.-1 in. ...	17.7	28.5						
1 in.-¾ in. ...	43.3	71.8						
¾ in.-20 mesh.	22.9	94.7						
20-48 "	2.5	97.2	14.0	14.0	26.6	26.6		
48-65 "	(a) 2.8	100.0	11.4	25.4	17.7	44.3	1.1	1.1
65-100 "	.....	.....	13.8	39.2	23.2	67.5	4.2	5.3
100-150 "	.....	.....	10.2	49.4	13.6	81.1	9.9	15.2
150-200 "	.....	.....	7.5	56.9	8.7	89.8	12.4	27.6
Below 200 "	.....	.....	43.1	100.0	10.2	100.0	72.4	100.0
	100.0		100.0		100.0		100.0	

(a) Includes all below 48 mesh.

The Chilean product is elevated to classifiers, from which the overflow goes to the slime-treatment department and sands to tube-mills; these are in closed circuit with classifiers, the overflow of which joins that



FIG. 3.—INSTALLATION OF LANE CHILEAN MILLS.

from the Chilean-mill classifiers and goes to the slime-treatment department. Table 2 gives screen analysis of the slimes as treated,

The first unit in the treatment department is composed of two Dorr thickeners in parallel, one 24 by 7 ft. and one 26 by 10 ft., the underflow, specific gravity 1.35, going to the first agitation unit composed of four 14 by 16 ft. tanks in series, where enough cyanide to increase the solution strength to 0.05 per cent. is added, and sufficient mill solution to make dilution $2\frac{1}{2}$ to 1; the overflow goes to clarifying leaves and precipitation.

TABLE 3.—*Mill Records for 1917—Treating 52,885 Dry Tons*

	Gold	Silver
Average value of feed, oz. per ton.....	0.5967	1.618
Average value of tails, oz. per ton.....	0.0217	0.381
Recovery, per cent.....	96.4	76.5
Combined recovery (money value), per cent.....		94.5
Net recovery.....		\$682,059
Ratio Au to Ag, in feed.....		1:2.7
Ratio Au to Ag, in tails.....		1:17.7

	Tons per Hour	Kw.-hr. per Ton
Symons No. 5 gyratory crusher.....	15.3	1.1
Lane Chilean mill (each).....	2.69	7.7
Tube-mill, 5 × 16 ft. (each).....	2.52	8.6 (a)
Thickening and agitation.....	.....	5.8
Filtering, clarifying, precipitating, refining, and assaying... ..	.....	1.5
Portland filters, 12 × 12 and 12 × 10 (both).....	4.03	
		24.7

(a) On basis of total mill feed; about 60 per cent. of total feed goes through tube-mills.

The second thickener unit is a 26 by 10-ft. Dorr single-tray. The underflow (specific gravity of tray product, 1.37—of tank compartment, 1.34) is raised 11 ft. net by a diaphragm pump, attached to each compartment, to the second agitation unit, which is a 26 by 20-ft. tank; here, sufficient overflow from No. 3 thickener unit is added by air lift to make the dilution $2\frac{1}{2}$ to 1. The overflow from the second goes to mill-solution tank or to precipitation, as conditions allow.

The third thickener unit is a 26 by 13-ft. Dorr single-tray, where the underflow (specific gravity tray product, 1.35—tank, 1.30) is raised $8\frac{1}{2}$ ft. net by a diaphragm pump attached to each compartment, to agitation unit No. 4, where sufficient barren solution is added by air lift to make the dilution $2\frac{1}{2}$ to 1; overflow goes by gravity, counter-current, to No. 2 thickener unit.

The fourth thickener unit is composed of two tanks, 24 by 7 ft. and 29 by 7 ft., in parallel, where barren solution and filtrate from the Portland vacuum filters are mixed with pulp entering thickeners; underflow, specific gravity 1.39, is raised $5\frac{1}{2}$ ft. net to the Portland filters, where pulp

TABLE 4.—*Costs per Ton for Milling 52,885 (Dry) Tons, 1917*

Department	Shifts Worked		Labor Costs		Material Costs		Power Costs	Total Costs
	Repairs	Operating	Repairs	Operating	Repairs	Operating		
			\$	\$	\$	\$	\$	\$
Rock breaking...	60	386½	0.0056	0.0267	0.0103	.....	0.0036	0.0462
Lane milling.....	495	1060½	0.0439	0.0814	0.0198	0.0491	0.0617	0.2559
Tube-milling.....	70¾	569	0.0073	0.0427	0.0127	0.1096	0.0702	0.2425
Chemical treatment.....	.....	70½	.....	0.0050	.....	0.3120	.....	0.3170
Agitating.....	927½	138¾	0.0091	0.0106	0.0134	.....	0.0238	0.0569
Thickening.....	82	139½	0.0084	0.0107	0.0069	.....	0.0229	0.0489
Filtering.....	101½	1084¾	0.0090	0.0833	0.0077	0.0185	0.0061	0.1246
Clarifying.....	4	277¾	0.0004	0.0213	0.0004	0.0022	0.0029	0.0272
Precipitating....	7	251¾	0.0006	0.0223	.....	0.1707	0.0010	0.1946
Clean-up and refining.....	4	324½	0.0004	0.0260	0.0013	0.0664	.....	0.0941
Tailings expense..	.....	626¼	.....	0.0447	.....	0.0197	.....	0.0644
Heating expense..	9½	105¼	0.0008	0.0072	.....	0.0422	.....	0.0502
Building maintenance.....	34	.....	0.0029	.....	0.0020	.....	.....	0.0049
General repairs...	1347½	.....	0.0152	.....	0.0186	.....	0.0023	0.0361
Miscellaneous expense.....	.....	344¼	.....	0.0496	.....	0.0078	0.0040	0.0614
Bullion expense...	.....	3	.....	0.0002	.....	0.0660	.....	0.0662
Oil, waste and packing.....	.....	.....	.....	.....	.....	0.0143	.....	0.0143
Assay expense....	.....	233¾	.....	0.0200	.....	0.0070	0.0032	0.0302
Totals.....	1095½	5614½	0.1036	0.4517	0.0931	0.8855	0.2017	1.7356

cake is given two washes of barren solution (one applied by a set of spray nozzles and a second by a perforated drip pipe), followed by a wash of water applied through perforated drip pipe. The filter cake, carrying 29.9 per cent. water, is then discharged as tailings and 20 per cent. more water is added to move it to the pond. The filter tailings are sampled by teeter-box sampler, operated by barren solution; the latter is also sampled by the same teeter-box. Overflow from the fourth thickener unit is pumped (counter-current) to No. 3 thickener.

The Portland filters require new filtering medium of cotton drill and burlap, and wire winding, every six to seven months; the filter is out of commission 28 to 36 hr. for removing worn wire and cloth, cleaning, applying new burlap and drill, and rewinding.

Pregnant solution going to precipitation is metered and sampled by a teeter-box holding 0.483 ton of solution per cycle; 3.81 tons of solution

TABLE 5.—*Principal Items in Cost of Milling 52,885 (Dry) Tons*

	Total Amount Used	Total Cost	Per Ton	
			Amount	Cost
Lane steel.....	21,576 lb.	\$2,596.79	0.41 lb.	\$0.0491
Grinding pebbles.....	534,000 lb.	5,796.85	10.10 lb.	0.1096
Cyanide.....	40,490 lb.	13,138.04	0.77 lb.	0.2484
Lime.....	585,823 lb.	3,352.99	11.08 lb.	0.0634
Zinc shavings.....	44,835 lb.	9,010.90	0.85 lb.	0.1704
Steam coal.....	489,000 lb.	2,167.35	9.25 lb.	0.0410
Borax glass.....	4,530 lb.	887.09	0.08 lb.	0.0168
Lumber-tailings dam.....	29,892 ft.	777.52	0.56 ft.	0.0147
Commercial hydrochloric acid.....	7,574 lb.	990.16	0.14 lb.	0.0187
Commercial sulphuric acid.....	17,819 lb.	488.46	0.34 lb.	0.0092
Fuel oil.....	1,210 gal.	176.98	0.02 gal.	0.0033
Diaphragms No. 4.....	222	579.80	.....	0.0110
Crucibles No. 275.....	23	1,351.46	.....	0.0255
Mint and express charges.....	.....	3,491.26	.....	0.0660
Elevator bucket belt, 13-in., 7-ply.....	.....	.....	.....	0.0017
Elevator buckets 12-in., 10-gal.....	.....	.....	.....	0.0013

are precipitated per ton of ore treated. Average value of pregnant solution is 0.152 oz. Au, and 0.354 oz. Ag; average value of barren solu-



FIG. 4.—BARNES-KING MILL, MARYSVILLE, MONT.

tion is 0.0023 oz. Au per ton. A vacuum system was applied to pregnant solution in November, 1917, but no definite results can be given at this time beyond stating that precipitation is uniformly lower than before its

adoption. Consumption of zinc shavings is 0.22 lb. per ton of solution precipitated.

TABLE 6.—*Wages Scale for 1917*

Average wages per shift.....	\$4.70
Precipitation men.....	5.00
Repair men.....	5.00
Chilean and tube-mill men.....	4.50
Solution men.....	4.50
Crusher men.....	4.00
Helpers.....	4.00

Monthly clean-up is usually made, requiring four men one shift each, to clean up and repack boxes, and two men five shifts each to treat and smelt precipitate, a total of 14 shifts per clean-up. The precipitate, after acid treatment and vacuum filtering, carries 47 per cent. moisture, and after drying and a partial roast, carries 67 per cent. bullion—0.278 fine gold, and 0.639 fine silver.

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Electrostatic Precipitation

BY O. H. ESCHHOLZ,* EAST PITTSBURGH, PA.

(Colorado Meeting, September, 1918)

THE electrostatic process of fume precipitation is an excellent example of the successful application of scientific knowledge to an industrial operation. Originally proposed for the precipitation of sulphuric acid mists, it has been extended until at present there is practically no fume-carrying gas to which the method cannot be applied. Among the more common applications are: the recovery of non-ferrous smelter flue-dust, iron blast-furnace dust, cement dust, and potash fume. It should be borne in mind that the process is restricted to the precipitation of suspended particles, either liquid or solid, and does not separate gaseous constituents. However, by proper temperature control, mixtures of vapors having different temperatures of condensation to either solids or liquids may be selectively precipitated.

The process consists essentially of subjecting suspended particles, including those too minute to be effectively acted upon by centrifugal or gravitational forces, to such an electrical force that they are driven from the gas stream, acting as a conveyer, and deposited upon a suitable receiving surface. This directional impulse is obtained from the interaction of charged particles and an electrostatic field of definite intensity gradient existing between two dissimilar electrodes, known as discharge and receiving electrodes. In principle, the equipment is equally simple. As shown diagrammatically in Fig. 1, it consists of:

- (1) A source of high-potential direct current, requiring:
 - (a) Source of alternating-current energy.
 - (b) Means of transforming from low voltage to high voltage.
 - (c) Means of converting alternating to direct current.
- (2) Precipitation chamber having:
 - (a) Transmission tubes for fume-laden gases.
 - (b) Suitably designed and disposed electrodes.
 - (c) Means for affecting removal of deposited solids.

Although Hohlfeld demonstrated, in 1824, that a smoke-laden atmosphere could be cleared by applying an electrostatic field, and while Sir

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Oliver Lodge and A. O. Walker recognized the metallurgical possibilities of that phenomenon in 1886, every attempt to commercialize electrical precipitation failed, due to the lack of a suitable supply of high-voltage energy. As Dr. Cottrell says,

The first step toward practicability was of necessity a commercially feasible source of high-tension direct current. The obstacles to building ordinary direct-current generators lie chiefly in difficulties of insulation, and if this is avoided in individual machines by working a large number in series, the multiplication of adjustable and moving parts intrudes itself. On the other hand, high-potential alternating current technique has in late years been worked out most thoroughly and commercial apparatus up to 100,000 volts and over has been available for some years The voltage is thus transformed and then commutated at a high potential by means of a synchronously rotating contact maker into an intermittent direct current. This

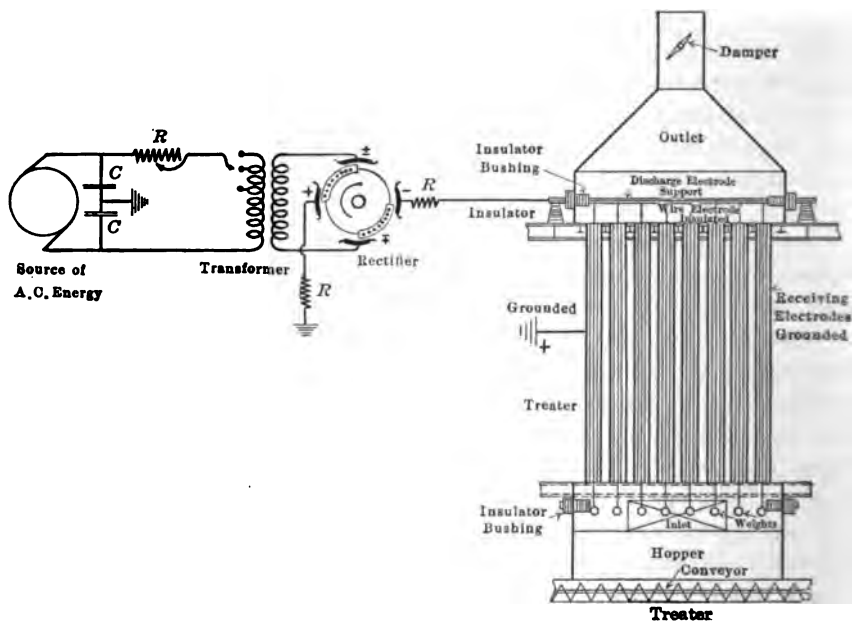


FIG. 1.—DIAGRAM OF TREATER CIRCUIT.

unidirectional current is then applied to a system of electrodes in the flues carrying the gases to be treated. . . . The development, therefore, may fairly be considered as the reduction to engineering practice, as regards equipment and construction, of the fundamental processes long since laid open by the pioneer work of Lodge, a feat vastly easier today than at the time of Lodge and Walker's original attempts.

In view of the important bearing that the development of electrical equipment has therefore had upon the commercializing of the precipitation process, it appears desirable to discuss briefly such apparatus, as well as some of the electrical phenomena characteristic of treater circuits.

ELECTRICAL SYSTEM

Systems depending upon the use of a mechanical rectifier for the conversion of high-tension alternating current to direct current may be classified with respect to the source of power.

A. Low-tension alternating-current generator for treater load only:

- (1) Single-phase generator supplying power to single transformer-rectifier-treater unit.
- (2) Single-phase generator supplying power to two or more transformer-rectifier-treater sets operated in parallel on the low-tension side.
- (3) Multi-phase generator supplying energy to one or more transformer-rectifier-treater sets from each phase.

B. Low-tension alternating-current industrial or lighting mains having a relatively large capacity as compared with treater demand, and supplying one or more transformer-rectifier-treater sets.

C. High-tension alternating-current main supplying energy directly to potential regulator-rectifier-treater sets.

System A-1

Of the above systems, A-1 is most widely used, the consensus of opinion being that this arrangement insures: (1) Continuity of operation; (2) greatest flexibility; (3) maximum dust recovery; (4) utmost simplicity of control and operation.

This system has the very apparent advantage of definitely isolating the circuit for each treater from the main plant circuits, as well as from every other treater, so that all disturbances are localized. Since each generator serves but one transformer-rectifier-treater set, close and efficient control of treater voltage is obtained by simply varying the generator excitation. The flexibility of this system is perhaps its greatest asset, enabling the operator to meet the many exigencies arising from varying gas characteristics and to maintain a high rate of fume recovery.

System B

System B has been applied to a relatively few installations in which the power requirement is large. Its chief merit lies in its low first cost. The equipment consists of a transformer-rectifier set (driven by synchronous motor) for each treater, with a series resistance in the primary circuit for securing control of treater voltage. Installations of this type have been usually viewed as temporary or experimental, and with increase in the units employed the following factors must be considered:

- (1) Effect of variations in supply-line on treater operation.

- (2) Effect of parallel transformer-rectifier-treater set operation, due to voltage wave distortion, on:
 - (a) Performance of other industrial and lighting apparatus.
 - (b) Treater performance.
- (3) Hazard to life and equipment caused by reflection of high-voltage surges on line.
- (4) Limited control of treater voltage obtainable by varying primary series resistance.
- (5) Maintenance of heavy current carrying variable-resistance contacts.
- (6) Increased power loss due to this type-of control.
- (7) Hazard of plant shut-down caused by treater disturbances.

Other Systems

Recognition of the remaining systems has been urged at various times on account of their smaller first cost and floor space. A careful analysis of practically every project, however, has revealed that such saving is accompanied by a greatly increased liability of interruption to service.

In this effort to reduce the initial investment, it is overlooked that, while the commercialization of precipitating processes hinges upon the development of electrical units, the average first cost of the electrical equipment of representative installations is actually a small part of the total, approximating usually 10 per cent. and, in rare instances, 15 per cent. of the cost of the treater. Moreover, the value of the yearly recovery from the average installation is at least twice the total investment, ranging from 150 to 600 per cent. of the total first cost, depending upon the type of construction required and the character of the material precipitated. The cost of the electrical equipment is, therefore, roughly from 2 to 7 per cent. of the value of the yearly recovery. The tendency among engineers is therefore toward the development and installation of rugged apparatus, having a liberal margin, to assure continuity of service.

In addition to suitable generator, transformer, and rectifier units, it has been found desirable to include certain auxiliaries in the circuit, such as permanent series resistances in the high and low tension lines to dissipate oscillating discharges and limit short circuits; and condensers, shunted across the generator leads, to absorb infrequent high-voltage surges reflected from the transformer windings to the generator armature.

TRANSFORMER

The extent to which the transformer incorporates the most advanced knowledge of high-voltage engineering is the measure of its success in precipitation service. Besides its obvious functions, it must bear the brunt of occasional surges caused by treater breakdown, and the periodic

oscillations produced at each half cycle on breaking the rectifier arc. Fig. 2 and 3 illustrate a type of construction in use in the majority of plants, which has demonstrated its ability to withstand, over a long period, the most severe operation encountered in precipitation service.

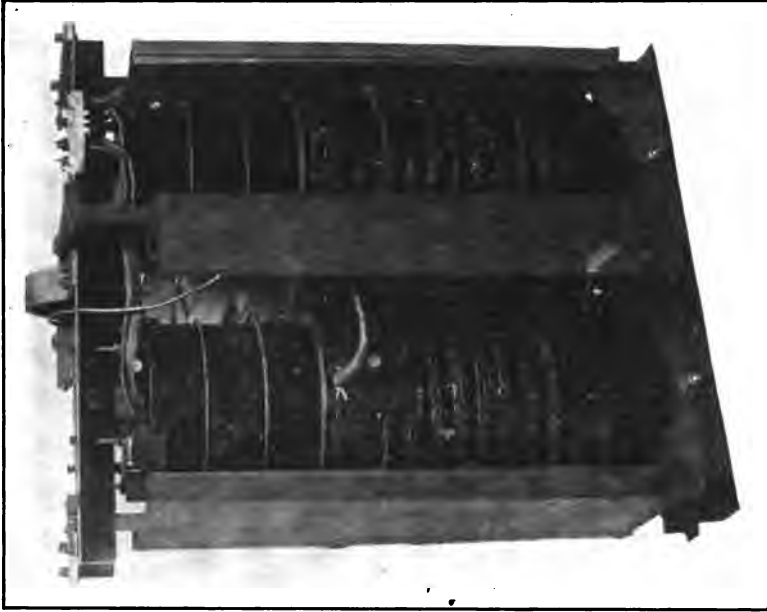


FIG. 3.—COILS OF 15 K. V. A. TRANSFORMER SHOWN IN FIG. 2.



FIG. 2.—15 K. V. A. 100,000-VOLT, 60-CYCLE TRANSFORMER FOR PRECIPITATION SERVICE.

RECTIFICATION

More dust is precipitated in a given time with a unidirectional field between electrodes than with an alternating field. With the latter, each reversal of field direction either retards the velocity of the charged

dust particles or completely reverses their direction, necessitating a larger and more expensive treater than is required with a field constant in direction. The problem of converting high-tension alternating current to high-tension unidirectional current has, therefore, received considerable attention. Although many devices, such as mercury rectifiers, hot-cathode converters, or kenotrons, high-voltage direct-current generators, unsymmetrical electrodes, etc., have been advocated, the mechanical rectifier is still in use on practically all commercial treater circuits. During more than 10 years, its peculiar fitness for this service

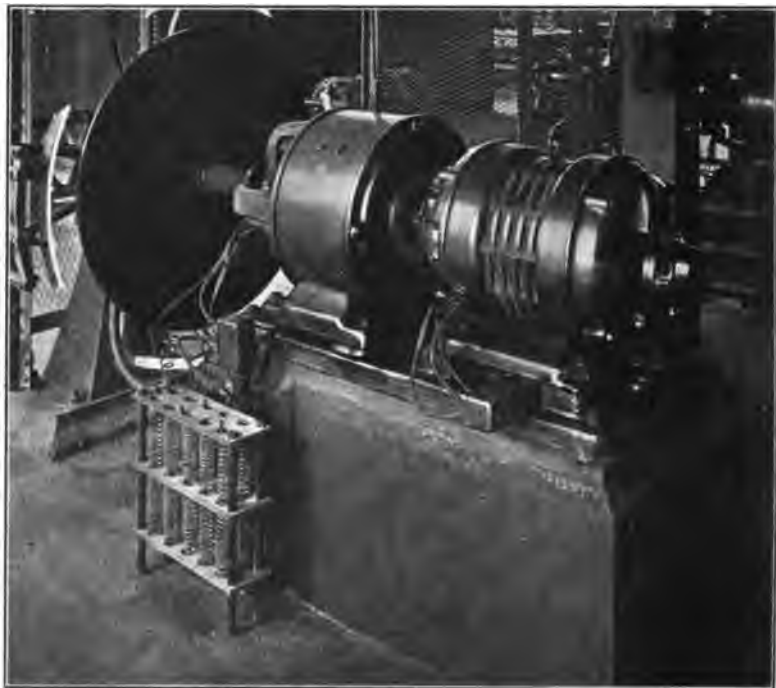


FIG. 4.—15 K. V. A. MOTOR-GENERATOR SET WITH DIRECT-CONNECTED DISK-TYPE RECTIFIER.

has been thoroughly demonstrated. As shown in Fig. 1 and 4, the rectifier consists of four stationary shoes, alternate ones being connected respectively to the transformer and the treater leads, and two conducting sectors mounted on the periphery of an insulating, rotating disk. During operation, the rotating sectors short-circuit adjacent and opposite shoes, so that at synchronous speed the alternating current is converted into direct-current impulses.

The noise accompanying the rapid breaking of the tail arcs as the rotating contacts recede from the collecting shoes is somewhat objection-

able. However, this is outweighed, in the estimation of operators, by such characteristics as:

- (1) Extreme simplicity in
 - (a) Operating principle.
 - (b) Mechanical and electrical construction.
- (2) Ease of adjustment to varying requirements.
- (3) Ruggedness, ease of repair and, therefore, low maintenance.
- (4) Low first cost.
- (5) Intermittent wave contact characteristic, which:
 - (a) Limits or suppresses treater short-circuits.
 - (b) Assists in sustaining treater voltage.

Despite the fact that the intermittent wave contact characteristic is well known as an inherent property of the rectifier, its effect on treater operation is not generally appreciated.

SUPPRESSION OF TREATER SHORT-CIRCUITS

Curve A, Fig. 5, illustrates a typical alternating-current or voltage wave obtained at the transformer high-tension terminals when operating on a resistance load without rectification. Curve B shows the wave form

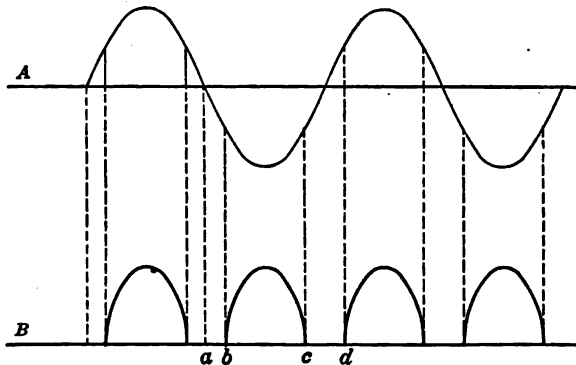


FIG. 5.—A. SINE-WAVE VOLTAGE OR CURRENT. B. UNIDIRECTIONAL VOLTAGE OR CURRENT WAVE OBTAINED ON RECTIFYING SINE WAVE A BY A MECHANICAL RECTIFIER WHEN SUPPLYING ENERGY TO A RESISTANCE LOAD.

modified by a mechanical rectifier. The period of wave contact $b-c$ is determined by the angle subtended by shoes, rotating sectors, and tail arcs, while the interval $a-b$ depends upon the length of gap between fixed and stationary conductors, and their position relative to the impressed wave when first making contact. Any section of the wave may be commutated by varying the length of rectifier shoes and adjusting them against or in the direction of the approaching wave front. Fig. 6 and 7 show, respectively, short and long periods of wave contact. Obviously, with the long contact, a greater amount of energy is transmitted.

Since a positive separation between the alternating and the unidirectional current circuits is secured during the interval $c-d$, a short-circuit occurring during the period of contact $b-c$ will be immediately interrupted by the electrode separation obtained during $c-d$. As most treater short-circuits are local, being caused by changes in gas condition, irregular accumulation of deposits, or swinging of electrodes, this rectifier characteristic enables the treater to relieve itself by a heavy local discharge in a period usually less than $\frac{1}{120}$ sec. with practically no interruption in operation or loss in recovery. It has been found possible, therefore, to operate Cottrell treaters for 24 hr. a day within 1 per cent. of the critical or breakdown voltage. Fig. 7 shows rectifier operation with the operating voltage maintained approximately 1 per cent. below critical voltage.

Fig. 8 shows the changes occurring in voltage (upper wave) and rectifier



FIG. 6.—RECTIFIER ADJUSTED FOR SHORT-ARC CONTACT.



FIG. 7.—RECTIFIER ADJUSTED FOR LONG-ARC CONTACT.

ground current (lower wave) during the interruption of normal operation by a short-circuit in the treater. It will be noted that the short-circuit occurred near the peak of the voltage ripple, and cleared in less than $\frac{1}{1000}$ sec., normal operation having been resumed in $\frac{1}{120}$ sec. Only a slight increase in the rectifier current is evident at the instant of short-circuit. The current peak following the resumption of service is due to the capacity current absorbed by the partially discharged treater. With any other commercial method of obtaining high-voltage direct current, such an incipient short-circuit would have developed into a heavy current, imposing severe strains on connected apparatus, until the more or less complex control switches had cleared the line.

The rectifier cannot, of course, suppress a sustained short-circuit

caused by complete breakdown in the treater chambers, or by contact of electrodes. Under such conditions, it operates to limit the current until the circuit breakers open; this latter type of disturbance, however, occurs infrequently.

TREATER VOLTAGE

As shown in Fig. 8¹ and particularly in Fig. 9,¹ the treater voltage is practically a flat wave. These oscillograms are typical of many that have been secured on treaters of different types and capacities. The inability of most investigators to record the treater-voltage characteristic is attributed to the use of an oscillograph of low sensitivity, or to excessive leakage of line, insulator, and treater current. The oscillograph, when connected as shown in Fig. 10, offers a discharge path for energy stored in the treater, and it is desirable, therefore, to use an



FIG. 8.

FIG. 8.—VOLTAGE ACROSS TREATER (UPPER WAVE) AND CURRENT THROUGH RECTIFIER GROUND LEAD (LOWER WAVE) IMMEDIATELY BEFORE AND AFTER SHORT-CIRCUIT IN TREATER CHAMBER. TIME INTERVAL BETWEEN WAVE PEAKS = $\frac{1}{120}$ SEC.

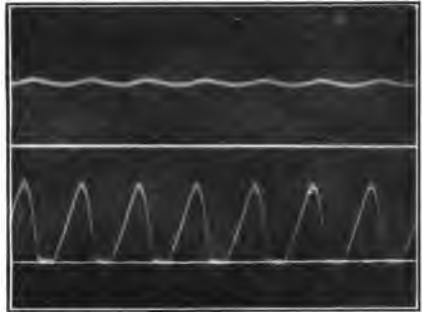


FIG. 9.

FIG. 9.—SHOWING SUSTAINED VOLTAGE ACROSS TREATER AND RECTIFIER GROUND CURRENT DURING NORMAL OPERATION. PEAK VOLTAGE 57,000; EFFECTIVE TREATER VOLTAGE APPROXIMATELY 97 PER CENT. OF PEAK. EFFECTIVE RECTIFIER CURRENT APPROXIMATELY 1 AMPERE.

instrument that will respond to the smallest changes of current; otherwise, the fluctuations in treater voltage appear greater than actually occur during normal operation. In all of the treaters examined, the effective voltage ranged from 90 to 97 per cent. of the maximum. To check the oscillograph observations, comparisons of the actual effective and maximum voltages were secured by means of an electrostatic voltmeter and a sphere gap, the instruments having been calibrated together on a commercial sine-wave voltage. Fig. 11 shows the variation in effective voltage with a change in load at a maximum treater voltage of approximately 55,000. It may be noted that, throughout the operating range, the effective value is close to 95 per cent.

¹These oscillograms were taken by H. I. Frisbie, Anaconda Copper Mining Co.

This sustaining of the treater voltage is caused by the comparatively slow rate of treater discharge. The suspended particles have usually an appreciable mass and, therefore, when charged under conditions where an arc is not formed, travel at low velocity. In fact, under the usual condition of moderate clearance of gas at a velocity of 6 ft. per second, obtained in a tube 12 in. diameter, 15 ft. long, the average velocity of the dust particles, at right angles to the gas stream is, roughly, but 0.8 in. per second, while complete precipitation of the same number of particles during the interval between breaking and making rectifier contact would require a velocity of 900 in. per second. Due to this slow rate of discharge, or ionic drift, the treater tends to maintain its voltage approximately constant, and the *rectifier practically operates to convert*

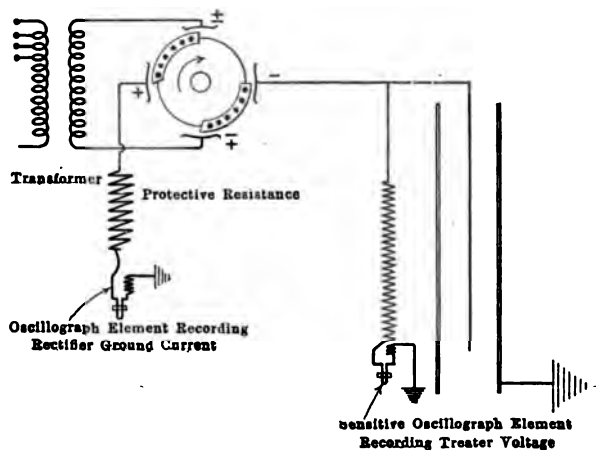


FIG. 10.—CONNECTIONS FOR OSCILLOGRAPH OBSERVATION.

a high-tension alternating current to a nearly constant high-tension direct current, so far as the flow across the gas space itself is concerned.

It is the author's opinion that a better utilization of the rectifier for suppressing short-circuits and sustaining treater voltage would result in improved clearance of dust, and increased returns on the investment.

OPERATING VOLTAGE

The treater voltage maintained with a given polarity of discharge electrodes is determined by such characteristics as velocity, temperature, conductivity, ease of ionization; also by electrode diameter, spacing, etc. In referring to the operating voltage, some confusion has resulted from the practice of assuming it as equivalent to the maximum effective voltage obtainable with a given transformer equipment. We hear repeatedly, therefore, of treaters operated at 100,000, 150,000 and even

250,000 volts, whereas very few commercial treaters are operating above 60,000 volts. The discrepancy between the assumed and the actual treater voltage is attributed to:

- (1) Use of a lower transformer ratio than the maximum.
- (2) Voltage drop across series resistances in high and low tension circuits.
- (3) Rectifier voltage drop.
- (4) Generator voltage distortion from sine to flat-top wave by rectifier and treater load characteristics.

With further development in the control of gaseous ionization and agglomeration of suspended solids, the critical voltage will un-

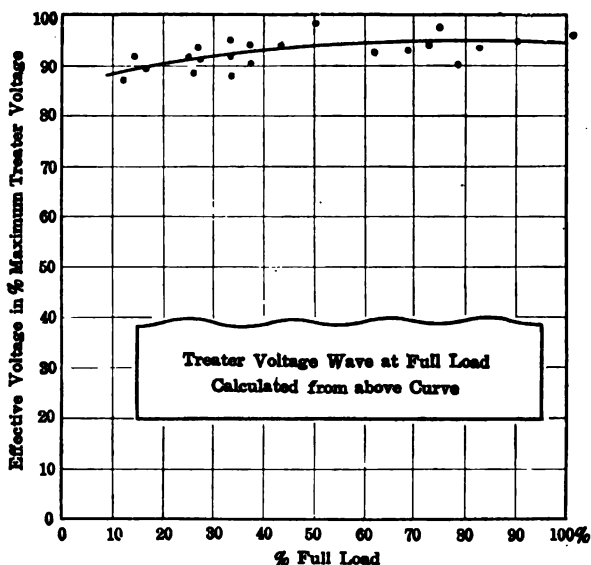


FIG. 11.—VARIATION IN TREATER EFFECTIVE VOLTAGE WITH CHANGE IN LOAD.

doubtedly be raised, and permit the use of a higher operating voltage with its attendant economies.

ELECTRODE VIBRATION

One of the treater phenomena associated with high-voltage operation is the tendency of electrodes to vibrate. Non-rigid electrodes, of either the chain or the wire type, have been observed to vibrate in circular and elliptical orbits, whether supplied with direct current from hot-cathode converters, Girvin high-voltage direct-current generator, or mechanical rectifiers. The vibration may be intermittent or sustained. Either type, however, is produced by unbalanced electrostatic forces pulling the discharge electrode toward the receiving electrode, thereby increasing the field intensity until a local arc ruptures the inter-

vening gas. This attractive force increases as the square of the voltage. At 25,000 volts, it is quite negligible; at 50,000 volts, it may seriously interfere with treater operation; while at 100,000 volts, non-rigid electrodes become impracticable and are preferably displaced by rigid electrodes. Vibration occurring at 50,000 volts may be almost eliminated by careful alignment of discharge electrode, and by the use of connecting damping rods or chains to alter the natural vibration period of the electrode system, and prevent it from oscillating in tune with the periodic treater arcing or voltage pulses.

TREATER PROBLEMS

In common with all radical developments, the electrostatic process is admittedly susceptible of further improvement. It is anticipated that valuable results will be obtained from the study of:

- (1) Variation of precipitation rate with:
 - (a) Change in gas velocity.
 - (b) Gas or vapor dilution.
 - (c) Accelerated agglomeration.
 - (d) Temperature change.
 - (e) Conductivity and ionizing potential of gases used.
 - (f) Conductivity, mass, dielectric constant of fume.
- (2) Methods for the removal of deposited material.
- (3) Control of gas distribution.
- (4) Control of the distribution and nature of deposits.

With regard to the last problem, Dr. E. R. Wolcott has shown that some deposits are essentially discontinuous dielectrics, particularly those obtained by the precipitation of cement dust, borax, etc., and form areas of high field density which reduce the critical and, therefore, the operating voltage from two-thirds to one-half of its initial value. The remedy now applied at a number of plants is to render the deposit conductive by subjecting the flue gases to a fine water spray. Where removal of the last traces of suspended fume is essential, as in the precipitation of potash, the absolute maintenance of a conductive deposit is assured by passing a continuous water film over the receiving electrodes. The potash treater recently installed at the Security Cement and Lime Co., Hagerstown, Md., embodies this development.

Investigations along the lines mentioned above will tend to:

- (1) Increase the percentage of recovery.
- (2) Decrease the cost of treater chambers, through increasing the rate of precipitation at high gas velocities.
- (3) Reduce operating cost and improve continuity of service through the development of automatic methods for the removal of deposits formed on either electrode.

SUMMARY

(1) The commercialization of the electrostatic precipitation process has pivoted about the development of transformers.

(2) The synchronous contact maker, or mechanical rectifier, besides converting high-tension alternating current to high-tension direct current, serves to: (a) Suppress treater short-circuits, and (b) sustain treater voltage, thereby permitting operation within a few per cent. of the critical voltage of the treater, while also maintaining a practically constant voltage, resulting in high recovery of suspended substances.

(3) Rapid progress is being made in the control of disturbing phenomena, inevitable with high-voltage operation.

(4) The precipitator investment is approximately 8 to 10 times that of the electrical equipment. Improvement in construction of the precipitator will show, therefore, a correspondingly greater reduction in total cost of installation.

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Development of the Coke Industry in Colorado, Utah, and New Mexico

BY F. C. MILLER,* TRINIDAD, COLO.

(Colorado Meeting, September, 1918)

THE metallurgical fuel of Colorado, Utah, and New Mexico has been a very tardy member in the caravan of western industrial progress. The history of western coke has naturally been closely related to the development of the metallurgy of iron and steel and the precious metals, in the State of Colorado.

It was at Leadville, with a population of 300 in 1877, that the *Sentinel* was published by Richard S. Allen. The *Sentinel* gave very full accounts of the various mineral discoveries at the new town of Leadville, which found their way to the more widely circulated journals of the East, and attracted the attention of many people. At the close of 1878, a census showed a total of 5040 persons.

The first smelter was established in 1877, at Malta, two miles from Leadville, by A. R. Meyer, but was not successful. It was succeeded by the Harrison Reduction Works, in 1878.

The La Plata began with one furnace in June, 1878, and in 1879 had four furnaces in active operation. These furnaces used charcoal for fuel, and, because of hot tops, suffered a tremendous loss in lead and silver. This difficulty was overcome by the erection of 50 single-bank 10-ft. beehive ovens at Crested Butte, Colo., in 1880. The slack coal sent to these ovens was very pure, and yielded a coke carrying as little as 4.5 per cent. ash.

Among the pioneers in the Leadville district were Grant, Eddy, James, Billings, Eiler, and Dickson. To these men the West owes the present expansion of its mining industry, and the erection of metallurgical processes for the treatment of precious metals.

On March 1, 1876, Pueblo was connected to the Atchison, Topeka & Santa Fe by the Pueblo & Arkansas Valley branch. The first smelter was erected in Pueblo by Mather and Geist. This modest plant grew into the immense Pueblo Smelting and Refining Co., now a part of the American Smelting and Refining Co. Coke for these small furnaces was made from unwashed Engleville coal, in 186 single-bank 12-ft. ovens at El Moro, in the Trinidad district, and it was not uncommon for the percentage of ash to exceed the percentage of fixed carbon in the coke.

On Jan. 23, 1880, the Colorado Improvement Co. consolidated

* Chief Chemist, Colorado Fuel and Iron Co.

with other companies to form the Colorado Coal and Iron Co., with Gen. William J. Palmer at the head. In 1881, this company erected a small iron and steel works at Bessemer, which has grown into the present Minnequa Plant of the Colorado Fuel and Iron Co. The early plant employed 900 men; the present plant employs over 7000 men. The Colorado Coal and Iron Co. never made a success with its steel venture at Bessemer, the principal cause of their failure being inferior coke, which contained 40 per cent. ash, had no strength to resist pressure, and was so fine in size that it filled the voids between the limestone and iron ore.

The reorganization of the Colorado Coal and Iron Co. in August, 1896, to the present Colorado Fuel and Iron Co. resulted in very active progress toward the improvement of its coke. Washeries, at that time, were not a staple on the market, and consisted chiefly in very costly experiments. Sopris was the first coke plant to have a fairly efficient washery. In 1899, the Colorado Fuel and Iron Co. purchased the patent right to the Forrester plunger jig, which became the standard unit for all of the washeries—Sopris, El Moro, Starksville, Segundo No. 1, Segundo No. 2, Tabasco, and Tercio—built in rapid succession during the years 1900 to 1902.

During this period, a great many standard batteries of double-bank 13-ft. ovens were constructed by the Colorado Fuel and Iron Co. and by coal companies operating in New Mexico and Utah. Previous to 1898, there were approximately 1600 coke ovens operating in Colorado, Utah, and New Mexico, without a single coal washery. At the end of 1902, there were 5900 coke ovens in operation, with 12 coal washeries. That short period will undoubtedly go down in history as the Coke Age of Colorado, Utah and New Mexico.

The Utah Fuel Co. erected ovens at Castle Gate, in 1888, to take care of the Montana trade, but after a brief period of operation, it was found that the coking property of the coal was rapidly deteriorating as the mine developed. An exhaustive examination of the entire property controlled by the Utah Fuel Co. resulted in the discovery of coking coal at Sunnyside. This coal does not possess uniform coking qualities, and it is necessary to disintegrate the slack to a fineness of $\frac{1}{8}$ in. before the best results can be obtained. Slack from this mine is low in impurity, yielding coke carrying about 12 per cent. ash.

In 1900, the Dawson Fuel Co., operated by the Phelps-Dodge corporation, at Dawson, New Mexico, erected 95 double-bank 13-ft. ovens and a washery, which gave the usual inefficient results. After a few years of experimenting with various jigs and other coal-washing appliances, they constructed an all-steel washery and assembled units of double-compartment jigs, concentrating tables, centrifugal driers, and appliances which make this washery second to none in the United States. In 1905, they erected 480 under-flue ovens. These ovens are 11 ft. in diameter,

of the bee-hive type, but the spent gases are carried through flues under the oven floor before going to a central spent-gas main leading to tall stacks. The hot gases are passed under boilers, but the system is so arranged that they can by-pass the boilers on their way to the stacks, or the boilers can be fired by hand if occasion should demand. A great saving in boiler fuel is accomplished by this form of oven construction, and the coke has a structure suitable for copper smelting. The product of these ovens is extracted with the Covington machine.

The Colorado Fuel and Iron Co. experimented with a similar oven, called a stack oven. This was of the bee-hive type, but the gases passed through flues under the floor and then up through a stack. The object was to coke the charge from the bottom up and from the top down in one operation, and reduce the time of coking from 48 to 24 hr. After several years of practice, the system was abandoned because there was not sufficient heat under the floor to make a dense coke; there was more sponge on the bottom of the prisms than on the top.

Mr. E. H. Weitzel was appointed Manager of the Fuel Department of the Colorado Fuel and Iron Co., in 1908, and began an active development in oven construction. Coke machines were installed at Segundo and Tabasco, and experiments were made on oven building. Previous to that date, oven retaining walls had been built of stone, laid with a batter of 2 or 3 in. The results of experiments show conclusively that reinforced concrete walls, without batter, are superior to stone. The retaining walls of the ovens constructed at Cokedale by the Carbon Coal and Coke Co., operated by the American Smelting and Refining Co., are reinforced concrete; they have been operating about 10 years with practically no repairs to the retaining wall.

The Covington coke extractor was introduced to offset the rapid decrease in available oven labor. It met this condition with a margin of profit in favor of the machine and, at the same time, the structure of the product was improved by making straight 72-hr. coke. The Koehler ovens, operated by the St. Louis, Rocky Mountain & Pacific, at Koehler, New Mexico, installed machines in 1915.

In 1909, the Colorado Fuel and Iron Co. shipped samples of coal to Joliet for a test in the Koppers byproduct ovens; the results were not satisfactory. In 1910, samples were shipped to Glasport, Pa., to be tested in the Otto Hoffman byproduct ovens; these tests were not all that could be desired, but they showed that a part of our western coal would make satisfactory coke in a byproduct oven. In 1916, another series of tests was made in the Koppers byproduct ovens at St. Louis, and the results proved satisfactory.

The H. Koppers Co., of Pittsburgh, has erected 120 ovens at Minnequa, Colo. They are divided into two batteries, and have a coking capacity of 46,000 tons per month; each oven is 40 ft. long, 10 ft. high

and 19 in. wide. It is presumed that the coking period will be between 16 and 18 hr. There is no definite decision as to the ultimate recovery of byproducts. Provision has been made at this time for the use of the excess gas, recovery of ammonium sulphate, recovery of tar and oils, and a special plant for benzol recovery. An approximate cost of \$5,000,000 will cover the ovens, coal washery, benzol plant, coke-screening plant, and various appliances. The plant began the manufacture of coke on July 8, 1918.

The Physical Properties of Western Coke

Coke	Number of Ovens	Apparent Specific Gravity	Per Cent. Coke	Per Cent. Cells	Weight per Cu. In., Grams	Crushing Strength, Pounds
Colorado Fuel & Iron Co., Colo.:						
Tabasco.....	302	0.842	47.31	52.60	13.80	1,620
Starkville.....	190	0.814	44.76	55.24	13.34	1,500
Sopris.....	272	0.988	54.06	45.94	16.11	2,500
Segundo.....	800	1.12	59.69	40.31	18.46	2,500
Tercio.....	600	0.818	45.54	54.46	13.40	1,560
Cardiff.....	165	0.785	43.23	56.78	12.84	1,553
Crested Butte.....	154	0.805	44.20	55.80	13.17	1,476
Victor American, Colo.:						
Delagua.....	160	0.722	38.34	61.66	11.63	1,120
Hastings.....	197	0.757	40.96	59.04	12.40	1,250
Gray Creek.....	99	0.793	42.12	57.88	12.70	1,300
Dawson Fuel, N. Mex.:						
Dawson.....	575	0.738	40.72	59.28	12.05	900
St. Louis, Rocky Mountain & Pacific, N. Mex.:						
Gardiner.....	184	0.752	40.41	59.59	12.29	1,163
Koehler.....	210					
American Smelting & Refining Co., Colo.:						
Cokedale.....	350	1.05	55.92	44.08	17.20	2,485
Durango.....	58	0.784	42.18	57.82	12.84	1,275
Utah Fuel Co., Utah:						
Sunnyside.....	566	0.783	44.53	55.46	12.80	1,546

Machine-drawn ovens: Segundo, 500; Koehler, 210; Tabasco, 302; Dawson, 480.

The average ash in Colorado and New Mexico coke is between 16 and 17 per cent.; in Utah coke, between 12 and 16 per cent.

The foregoing table shows the physical properties of the coke produced in the ovens of Colorado, Utah, and New Mexico.

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Staggering Locations for Oil Wells

BY ROSWELL H. JOHNSON, M. S., PITTSBURGH, PA.

(Colorado Meeting, September, 1918)

THE prevailing system of wells on a rectangular basis, as shown in Fig. 1-A, has developed because of the exigencies of offsetting at boundary lines. When, however, a very large tract is being drilled, it is often possible to abandon this inferior method for the superior arrangement

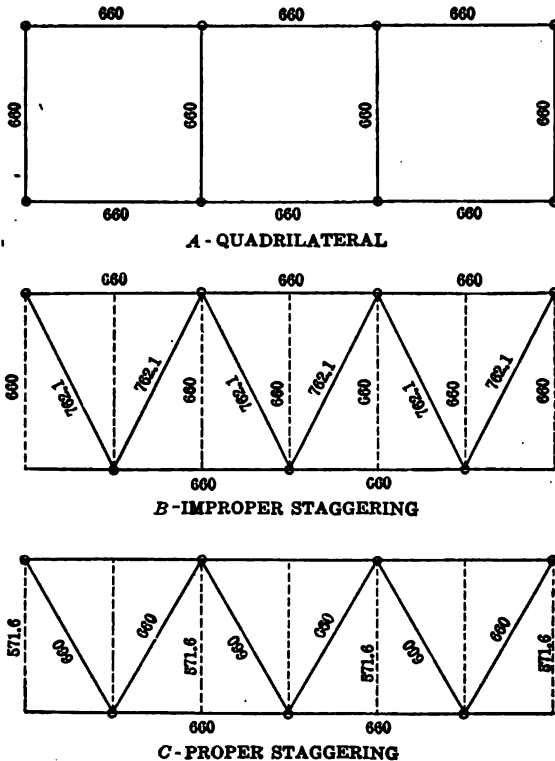


FIG. 1.—THREE SYSTEMS OF SPACING WELLS.

known as "staggering," which is illustrated in Fig. 1, B and C. The advantages of the triangular over the rectangular method are evident from Fig. 2, computed on the basis of one well to 10 acres (4 ha.). With the triangular system, no land is more than 409.4 ft. (124.8 m.) from a

well, while with the rectangular system, 14,400 sq. ft. (0.33 acre or 0.13 ha.) lies more than that distance from a well.

The purpose of this contribution is to assist the producer in planning

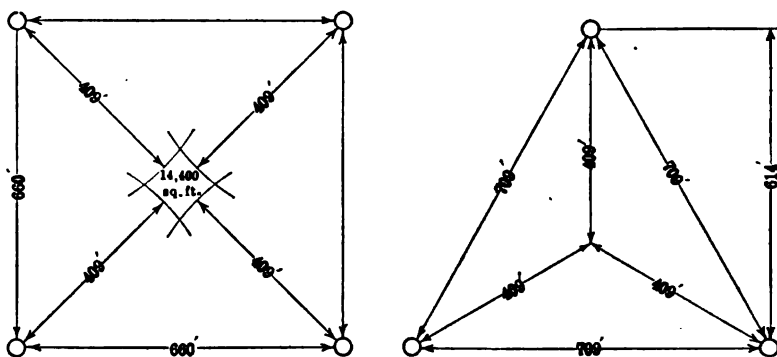


FIG. 2.—QUADRANGULAR AND QUINCUNX ARRANGEMENTS COMPARED, ON BASIS OF ONE WELL TO 10 ACRES.

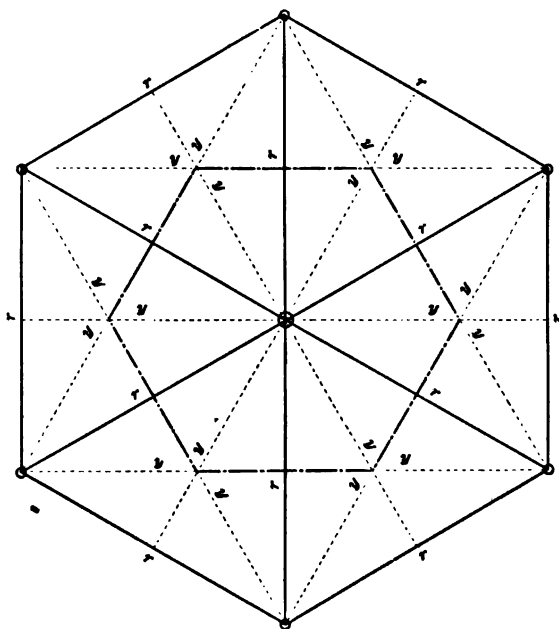


FIG. 3.—DIAGRAM FOR DEMONSTRATING FORMULAS FOR EQUILATERAL TRIANGULAR ARRANGEMENT OF WELLS, WHERE y = DISTANCE BETWEEN ROWS, r = DISTANCE BETWEEN WELLS.

the staggering arrangement of wells. Some companies, in staggering wells, have retained the same distance between the rows as between the wells in the row (Fig. 1-B), but to get equal distances between any two adjacent wells, which is desirable in order to yield maximum drainage,

the triangles must be equilateral, which necessitates the shortening of the distance between the rows (Fig. 1-C), making the quincunx arrangement, as customary in arranging tank farms.

The formulas for computing the distance between wells thus arranged were derived from Fig. 3, representing a well surrounded by the six nearest wells; the dot-dash line midway between the central and the surrounding wells outlines the hexagon drained by this well. This hexagon consists of 12 right triangles, each of the triangles having as its altitude one-half the distance between the wells (r), and as its base one-third the

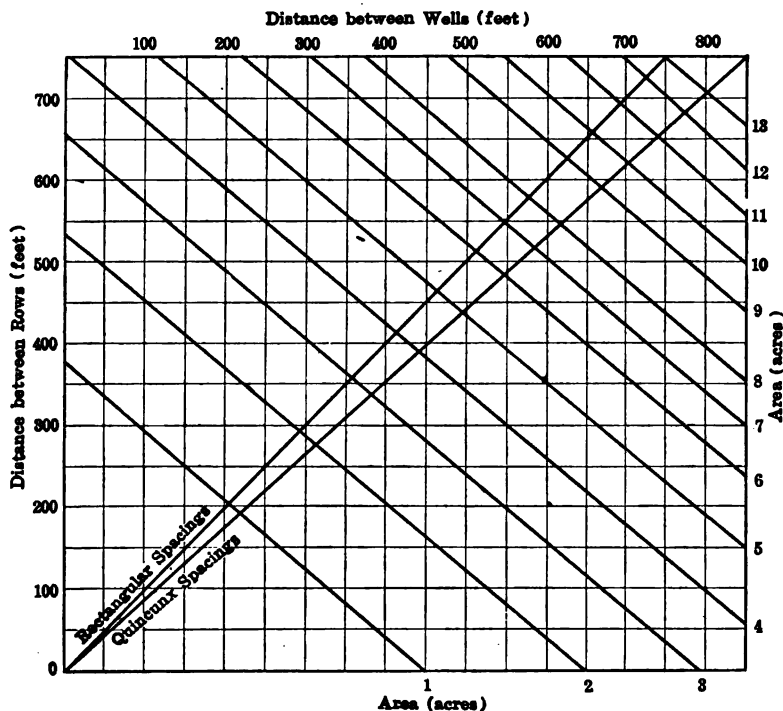


FIG. 4.—GRAPHIC REPRESENTATION OF RELATION OF DISTANCE BETWEEN ROWS, DISTANCE BETWEEN WELLS, AND AREA (IN ACRES) TRIBUTARY TO EACH WELL.

distance between the rows (y). The hexagonal area drained by each well therefore reduces to ry .

To obtain the relationship of the distance between rows (y) to the distance between wells (r), it is only necessary to remember that the right-angled triangle having these two distances for its sides has angles of 30° and 60° . By the geometric properties of the equilateral triangle,

$$r : y :: 2 : \sqrt{3}$$

$$y = \frac{r}{2} \sqrt{3} = 0.866r$$

Correspondingly, $r = 1.154734y$

To obtain r when the area tributary to one well is given: knowing that area $= ry$, and that $y = 0.866r$,

$$\text{Area} = 0.866r^2 \text{ or } 1.155y^2$$

Using these formulas, Table 1 is so arranged that for a given distance between wells, the appropriate distance between rows, and the area in square feet and in acres tributary to each well, may be read at once where the arrangement is by equilateral triangles. Similarly, Table 2, for a given distance between rows, shows the corresponding distance between wells, and the area tributary to each. Table 3 gives the proper distance between wells and between rows for a given area tributary to one well.

These relationships can be shown graphically, as in Fig. 4, from which smaller, intermediate, and larger values may be obtained, the diagram thus being useful for arranging tanks and gas wells, and for other purposes. Beginning at the lower left-hand corner of Fig. 4, the upper line gives the appropriate distances where the arrangement is rectangular, and the lower line the distances where the arrangement is in equilateral triangles (quincunx). The diagonal lines crossing these show the area per well, in acres.

TABLE 1.—*Quincunx Arrangement, Distance between Wells Given*

Distance between Wells, Ft.	Distance between Rows, Ft.	Area per Well		Distance between Wells, Ft.	Distance between Rows, Ft.	Area per Well	
		Sq. Ft.	Acres			Sq. Ft.	Acres
300	259.8	77,940	1.79	500	433.0	216,500	4.97
310	268.5	83,235	1.91	510	441.7	225,267	5.17
320	277.1	88,672	2.04	520	450.3	234,156	5.38
330	285.8	94,314	2.17	530	459.0	243,270	5.58
340	294.4	100,096	2.30	540	467.6	252,504	5.80
350	303.1	106,085	2.44	550	476.3	261,965	6.01
360	311.8	112,248	2.58	560	485.0	271,600	6.23
370	320.4	110,548	2.72	570	493.6	281,352	6.46
380	329.1	125,058	2.87	580	502.3	291,334	6.69
390	337.7	131,703	3.02	590	510.9	301,431	6.92
400	346.4	138,560	3.18	600	519.6	311,760	7.16
410	355.1	145,591	3.34	610	528.3	322,263	7.40
420	363.7	152,754	3.51	620	536.9	332,878	7.64
430	372.4	160,132	3.68	630	545.6	343,728	7.89
440	381.0	167,640	3.85	640	554.2	354,688	8.14
450	389.7	175,365	4.03	650	562.9	365,885	8.40
460	398.4	183,264	4.21	660	571.6	377,256	8.66
470	407.0	191,290	4.39	670	580.2	388,734	8.92
480	415.7	199,536	4.58	680	588.9	400,452	9.19
490	424.3	207,907	4.77	690	597.5	412,275	9.46

TABLE 2.—*Quincunx Arrangement, Distance between Rows Given*

Distance between Rows, Ft.	Distance between Wells, Ft.	Area per Well		Distance between Rows, Ft.	Distance between Wells, Ft.	Area per Well	
		Sq. Ft.	Acres			Sq. Ft.	Acres
250	288.7	72,175	1.66	480	554.3	266,064	6.11
260	300.2	78,052	1.79	490	565.8	277,242	6.36
270	311.8	84,186	1.93	500	577.4	288,700	6.63
280	323.3	90,524	2.08	510	588.9	300,339	6.89
290	334.9	97,121	2.23	520	600.5	312,260	7.17
300	346.4	103,920	2.39	530	612.0	324,360	7.45
310	358.0	110,980	2.56	540	623.6	336,744	7.73
320	369.5	118,240	2.71	550	635.1	349,305	8.02
330	381.1	125,763	2.89	560	646.7	362,152	8.31
340	392.6	133,484	3.06	570	658.2	375,174	8.61
350	404.2	141,470	3.25	580	669.7	388,426	8.92
360	415.7	149,652	3.44	590	681.3	401,967	9.23
370	427.3	158,101	3.63	600	692.8	415,680	9.54
380	438.8	166,744	3.83	610	704.4	429,684	9.86
390	450.3	175,617	4.03	620	715.9	443,858	10.19
400	461.9	184,760	4.24	630	727.5	458,325	10.52
410	473.4	194,094	4.46	640	739.0	472,960	10.86
420	485.0	203,700	4.68	650	750.6	487,890	11.20
430	496.5	213,495	4.90	660	762.1	502,986	11.55
440	508.1	223,564	5.13	670	773.7	518,379	11.90
450	519.6	233,820	5.37	680	785.2	533,936	12.26
460	531.2	244,352	5.61	690	796.8	549,792	12.62
470	542.7	255,069	5.86	700	808.3	565,810	12.99

TABLE 3.—*Quincunx and Quadrangular Arrangements, Area per Well Given*

Area per Well		Quincunx		Quadrangular
Acres	Square Feet	Distance between Wells, Ft.	Distance between Rows, Ft.	Distance between Wells, Ft.
0.5	21,780	158.6	137.3	147.6
1.0	43,560	224.3	194.2	208.7
1.5	65,340	274.7	237.8	255.6
2.0	87,120	317.2	274.7	295.2
2.5	108,900	354.6	307.4	330.0
3.0	130,680	388.5	336.4	361.5
3.5	152,460	419.6	363.3	390.5
4.0	174,240	448.6	388.5	417.4
4.5	196,020	475.8	412.0	442.7
5.0	217,800	501.5	434.3	466.7
5.5	239,580	526.0	455.5	489.5
6.0	261,360	549.4	475.8	511.2
6.5	283,140	571.8	495.2	532.1
7.0	304,920	593.4	513.9	552.2
7.5	326,700	614.2	531.9	571.6
8.0	348,480	634.4	549.3	590.3
8.5	370,260	653.9	566.3	608.5
9.0	392,040	672.8	582.6	626.1
9.5	413,820	691.3	598.7	643.3
10.0	435,600	709.2	614.2	660.0
10.5	457,380	726.7	629.3	676.3
11.0	479,160	743.8	644.1	692.2
11.5	500,940	760.6	658.7	707.8
12.0	522,720	776.9	672.8	723.0

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Lithology of the Berea Sand in Southeastern Ohio, and Its Effect on Production

BY L. S. PANYITY,* COLUMBUS, OHIO

(Colorado Meeting, September, 1918)

THE State of Ohio is among the pioneers in the production of oil and gas. Numerous anticlinals, such as the Macksburg, Cow Run and Newport, have been thoroughly developed, and the pools found in connection with them are quite in accord with the structural theory. Numerous oil and gas pools found in the Berea sand, however, demand a different explanation.

The study of these pools belongs to the sub-surface geologist, as it is possible to understand the factors controlling "off-structure" accumulations only after a careful study of well records. By carefully analyzing the various conditions over a large territory, it is possible to understand the otherwise meaningless mass of data that one may have at hand, and put it into tangible shape, from which various conclusions may be drawn.

The territory here discussed includes Belmont, Guernsey, Muskingum, Noble, Monroe, Morgan, Washington, Athens and Meigs counties, containing the majority of the prolific oil and gas pools of the Carboniferous system in southeastern Ohio.

The general dip of the strata is to the southeast, the entire territory lying on the northwestern flank of the Appalachian geosyncline. The best known oil- and gas-producing horizon in the territory is the Berea sand, which lies near the lower part of the Mississippian, with the Sunbury shales (the coffee-shales of the driller) above, and the Bedford shales below it. The Bedford is underlain by the thick Ohio shales. The Ohio and Bedford contact is considered to be the dividing line between the Carboniferous and Devonian systems.

The Berea is one of the most persistent of recognizable oil and gas horizons; its outcrop has always been found in its expected place, and it has always been penetrated whenever the drill went deep enough. It is not expected, however, even of the most uniform formations, that no lithological variations should occur, and the Berea is no exception. Nevertheless, there appears to be a certain regularity in its variation, the main features of which directly affect the accumulation of petroleum.

* Geologist, Ohio Fuel Supply Co.

It is the purpose of this paper to point out this characteristic condition in the sand, and to attempt to show its observed effects on production.

The first noticeable feature of the Berea sandstone is that the formation is thickest at its outcrop, being between 50 and 60 ft. (15 and 18 m.) in average thickness. This thickness is maintained down the dip for a great distance, when suddenly the sand becomes thin, and remains so. This thinning seems to appear in a well-defined zone. From a study of well records near McConnelsville, Guysville, and Bedford, it is noticed that the Berea appears to be in three strata. First, a top layer of sand about 35 ft. (10 m.) thick, which is invariably full of water. Below this is a shale "break" of about 25 ft., then a lower and thinner sand, from

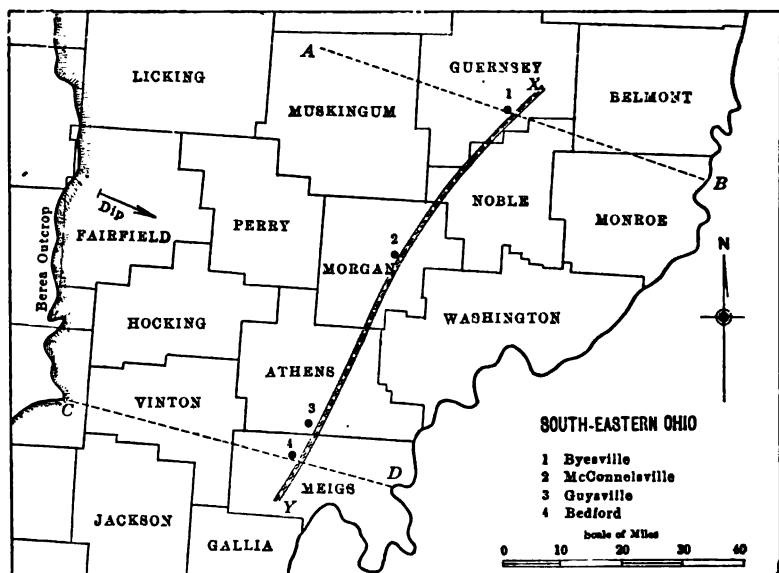


FIG. 1.

1 to 15 ft. thick; this lowest, or thin stratum, is the "pay sand" (Fig. 2 and 3).

In the vicinity of Byesville, north of the places above mentioned, this double structure of the sand is altered, and the thick and thin strata do not overlap. The change is shown by a sudden thinning of the thick water-bearing formation; then to the east follows a conspicuous territory of "no-sand," and further east the thin sand makes its appearance (Fig. 4).

Connecting the points where the change in the sand is noticeable, a hypothetical line (X - Y in Fig. 1) is obtained, running a little east of north. In the territory under discussion, the line is quite well defined and its position may be located from well records. North of this territory, its course is not so easily followed; the direction of the line appears to

change and at Byesville it seems to bear to the east. In this district the drill generally stops when the water in the thick sand is found, so the presence or absence of the thin lower sand is not known.

THIN-SAND TERRITORY

In the territory east of the line, the sand everywhere is found to be thin, and quite lenticular. The position of the thin sand near the line is up the dip, and the best gas fields in the Berea are found near this (western) limit of the sand; east, and parallel with the line, are such gas

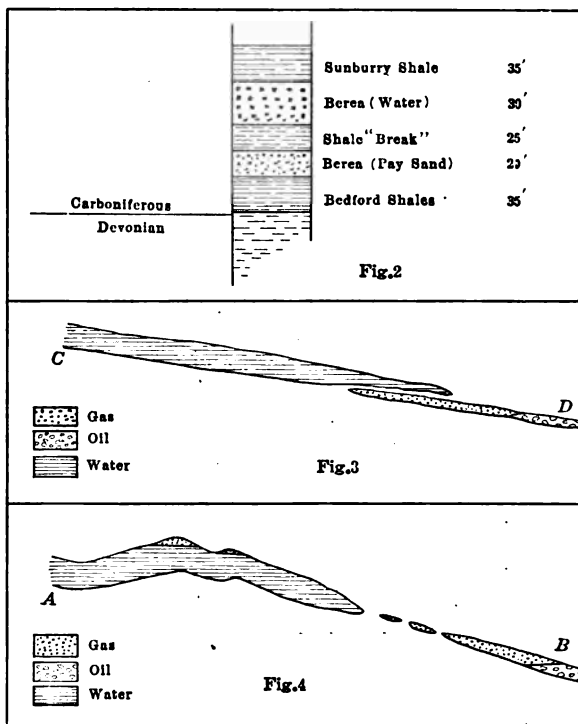


FIG. 2, 3 and 4.

fields as Barnesville, Temperanceville, Summerfield, Macksburg, Dudley, McConnelsville, and Rutland. East of the gas, down the dip, the best Berea oil pools are found. Little water is found in this stratum below the oil. In places where anticlinal structure is present, the gas, oil and water are found in relative positions in accordance with the structural theory, but the controlling factor in most of these pools is the western limit of the thin sand, in proximity to the hypothetical line. The oil found in this sand is of the highest, or Pennsylvania, grade.

THICK-SAND TERRITORY

In the territory west of the line, a thick water-bearing sand is present throughout. The pools are few and very small, the only one of any magnitude being the Corning. The oil in this field is of a lower grade than the thin-sand oil, and is known as Corning grade. Two small pools, the Oakgrove and Otsego, lying northeast and northwest of Byesville, are also in the thick-sand territory, the former being on a strong anticlinal "nose," the latter on the flank of an anticlinal fold, with gas at the top. In almost every instance, when the drill reaches this thick sand, a showing of dark oil is found, and the few scattered small pools in this sand are no doubt associated with "structure." However, the territory west of the line appears to be free of prominent structural disturbances, which is of the greatest importance in a district where connate water is found in great quantity in the sand.

CONCLUSION

It will be noticed that the thin-sand territory is by far the better oil and gas producer of the two, and the size and staying qualities of the wells are much better than of those in the thick-sand district.

It appears possible that these two horizons are entirely separate strata; the up-dip limit of the lower, thin sand, and the lower limit of the upper, thick sand, however, appear to be too closely related to permit such a conclusion. A close study of numerous well records in proximity with the hypothetical line would no doubt throw more light on this question. A better understanding of the lithology of the Berea sandstone could be obtained, I believe, by the study of that portion of its outcrop which parallels Lake Erie and passes eastward into Pennsylvania.

It has long been the belief of a number of practical oil and gas men, based on personal experience, that a thick Berea sand is not a good producing stratum in Ohio. One cannot but agree with them, and it is hoped that the conditions here described account for this belief.

TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS
[SUBJECT TO REVISION]

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The Manufacture of Ferro-alloys in the Electric Furnace

BY ROBERT M. KEENEY,* E. MET., DENVER, COLO.

(Colorado Meeting, September, 1918)

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* Manager, The Ferro Alloy Co.; Manager, The Iron Mountain Alloy Co.

INTRODUCTION

Before the outbreak of the war in 1914, the only electric-furnace smelting plant operating on a commercial basis west of the Mississippi River was an electric pig-iron plant in California; rare metal ores were not smelted, concentrates of molybdenum, tungsten, uranium, and vanadium ores being shipped east for reduction. Practically no chrome ore was being mined, and only comparatively small amounts of manganese ore. Today there are two electric smelting plants in California, one in Washington, one in Iowa, and four in Colorado; two plants are under construction in California, and one in Montana. Ores of manganese, chromium, molybdenum and tungsten are now smelted in the West, and although uranium and vanadium concentrates are still shipped to the East, they will probably be treated in western plants in a short time. The four electric-furnace plants in Colorado are listed in Table 1.

TABLE 1.—*Electric Smelting Plants in Colorado*

Company	Location	Capacity, Kilowatts	Products
Tungsten Products Co.....	Boulder	800	Ferrotungsten, ferromolybdenum.
Boulder Tungsten Production Co..	Boulder	400	Ferrotungsten.
Ferro Alloy Co.....	Utah Junction	1200	Ferrochrome, ferrotungsten.
Iron Mountain Alloy Co.....	Utah Junction	3000	Ferromanganese.

Power for all of these plants is supplied by the Colorado Power Co.

Ferro Alloy Company's Plant

The plant of the Ferro Alloy Co., at Utah Junction, contains one 750-kw., three-phase furnace, to which power is supplied by three 250-kw. transformers, connected Δ/Y to give 129 volts on the furnace cables, the transformer ratio being 13,200 to 75 volts. The furnace operates with an actual voltage of 120 volts, and produces about 3 tons of ferrochrome per 24 hr. from 40-per cent. Cr_2O_3 ore. The furnace consists of a steel shell of circular cross-section, 8 ft. (2.43 m.) in diameter by 7 ft. (2.13 m.) deep, lined with magnesite, and having three vertical carbon electrodes 12 in. (30.48 cm.) in diameter.

A 450-kw. furnace, of the same size as the 750-kw. furnace, is also operated on chrome ore. This furnace is three-phase in appearance, but operates electrically as a single-phase furnace. There are three vertical carbon electrodes 8 in. (20.32 cm.) in diameter with a conducting carbon bottom. Power is supplied by three 150-kw., single-phase transformers, two of which have a ratio of 13,200 to 95 volts, and one a ratio of 13,200 to 100 volts. From each transformer, one lead goes to one vertical electrode, and one lead to the carbon bottom, so that the transformers are

electrically independent. The furnace voltage varies from 90 to 95 volts.

At intervals, 150-kw., single-phase furnaces are operated on ferro-tungsten. These furnaces have one vertical graphite electrode 4 in. (10.16 cm.) in diameter, with a water-cooled steel bottom contact. The furnace shells are 4 ft. (1.22 m.) in diameter, and are mounted on trunnions, the slag being poured by tilting the furnace. All of the electrodes are regulated by hand. The chrome furnaces are operated without roofs and the tungsten furnaces with roofs. The whole plant has a power factor of 90 per cent.

Iron Mountain Alloy Company's Plant

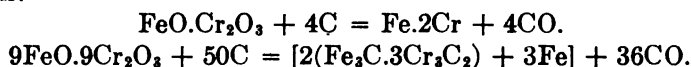
The plant of the Iron Mountain Alloy Co., at Utah Junction, contains one 1200-kw., three-phase furnace, and one 1800-kw., three-phase furnace, giving a total capacity of 12 long tons of ferromanganese per 24 hours.

The 1200-kw. furnace is supplied with power by three 400-kw., single-phase transformers, having a ratio of 13,200 to 75 volts, and connected Δ/Δ . The voltage on the furnace is 72 volts. The 1800-kw. furnace is connected to three 600-kw., single-phase transformers having a ratio of 13,200 to 75 volts, and connected Δ/Δ . The power factor of the plant is 85 per cent.

The furnace shells in both cases are 18 ft. (5.48 m.) long, 8 ft. (2.43 m.) wide, 7 ft. (2.13 m.) deep, and are lined with magnesite. The electrodes on the smaller furnace are of carbon, 17 in. (43.18 cm.) in diameter, and on the large furnace 24 in. (60.96 cm.) in diameter; in both furnaces, they are threaded for continuous feeding. No roofs are used, and regulation of electrodes is by hand.

FERROCHROME

The process of making ferrochrome from domestic chromite ore consists of mixing ore, coal or coke, lime, fluorspar, or silica, in proper proportions, and smelting this mixture in an electric furnace. At 2-hr. intervals, the ferrochrome and slag are tapped into iron pots, the metal settling to the bottom. The pot is dumped when the contents are solidified. Reduction theoretically takes place according to the reaction:



Domestic Chrome Ores

In smelting domestic ore, which has a higher percentage of slag-forming constituents than foreign ore, and averages 40 to 45 per cent. Cr_2O_3 , considerably higher loss of chromium occurs and it is more difficult to

control the carbon content of the product. By permitting a higher slag loss, the carbon can be kept below 6 per cent., but varies between 4.5 and 8 per cent. The products are sorted into ferrochrome with 6, 7, and 8 per cent. carbon; the greatest demand is for the 6-per cent. carbon product, but large quantities of the other grades are used by the

TABLE 2.—*California and Oregon Chromite Ores*

	1	2	3	4	5	6	7	8	9	10	11	12
	%	%	%	%	%	%	%	%	%	%	%	%
Cr ₂ O ₃	51.40	46.45	42.25	42.50	42.80	50.50	48.10	44.43	41.90	44.08	34.27	41.91
FeO.....	16.71	13.88	13.37	13.11	14.14	10.54	13.63	15.42	15.42	11.57	11.05	15.42
Al ₂ O ₃	17.26	26.00	13.40	19.66	15.08	19.98	17.54	14.30	16.60	20.80	11.90	16.60
MgO.....	6.60	7.89	13.02	8.37	8.04	11.00	12.20	13.76	12.82	16.15	21.30	12.82
CaO.....	Tr.	Tr.	1.00	Tr.	0.80	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.
SiO ₂	4.26	6.60	8.84	5.48	9.94	4.90	5.30	9.44	8.70	6.90	21.70	8.70
Sulphur.....	0.093	0.063	0.07	0.44	0.233	0.022	0.037	0.035	0.025	0.030	Tr.	0.025
Phosphorus.....	0.038	0.02	0.03	0.049	0.065	0.063	0.034	0.043	0.036	0.024	0.035	0.036
Copper.....	0.06	0.02	0.007	nil	nil	0.09	0.09	0.003	0.004	0.004	0.004	0.004
Arsenic.....	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil
Tin.....	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil

steel industry. The iron content of domestic ores is higher than that of foreign ores, with the result that the chromium content of the product varies from 60 to 65 per cent. instead of 65 to 70 per cent.

Analyses of typical domestic ores are given in Table 2, the ore all having been produced in California or Oregon. The analyses represent

carload shipments; No. 1 to 7 were produced in 1917, and the rest in 1918; the decreasing grade of the ore is noticeable.

Effect of Grade of Ore, Grade of Product, and Constituents of Charge, on Recovery and Carbon Control

In smelting chrome ore to produce a ferrochrome with 8 per cent. carbon, considerably higher recovery can be attained than when making

TABLE 3.—*Production of Ferrochrome with 6 to 8 Per Cent. Carbon*

	1	2	3	4	5	6	7	8	9	10	Average
Charge:											
Chrome ore, lb.....	11,890	10,333	11,223	12,211	12,858	13,238	12,533	12,150	12,703	12,355	
Coke, lb.....	3,961	3,411	3,643	3,847	4,188	4,071	3,615	3,423	3,063	3,617	
Lime, lb.....	132	115	122	105	165	308	394	235	116	465	
Fluorspar, lb.....	332	298	300	80	167	192	202	192	151	182	
Slag, 20% Cr, lb.....	2,099	1,821	1,933	2,155	2,268	2,334	3,552	4,088	3,966	4,901	
Ferrochrome:											
Chromium, %.....	65.20	65.80	65.20	64.50	64.00	63.80	64.10	65.70	64.90	63.2	64.64
Carbon, %.....	6.75	6.80	6.25	6.47	6.73	6.17	7.67	7.81	7.09	7.77	6.95
Slag:											
Chromium, %.....	4.20	5.60	3.68	5.75	5.50	4.53	4.30	4.45	9.54	4.53	5.21
Carbon charged per 100 lb. chrome ore, lb.....	18.9	18.9	18.4	17.9	18.6	17.6	16.5	16.1	13.8	16.8	17.3
Weight ferrochrome, lb.....	5,286	5,139	5,327	6,529	6,909	6,977	6,809	7,039	6,598	7,142	
Weight chromium, lb.....	3,430	3,380	3,479	4,210	4,422	4,447	4,378	4,639	4,261	4,508	
Weight slag, lb.....	5,261	4,777	4,370	6,038	4,793	6,004	8,157	8,678	8,349	8,497	
Chromium recovered, %.....	88.5	99.2	95.2	97.7	97.8	95.3	93.4	96.2	85.75	91.7	94.07
Kw.-hr. per lb. ferrochrome.....	4.36	3.9	3.57	3.68	3.19	3.42	2.50	3.7	3.04	3.65	3.50

Note.—Recovery is based on metal output, and ore and slag charged. The operations were conducted in three 150-kw. furnaces and three 250-kw. furnaces.

a 6-per cent. carbon product, for two reasons: (1) excess of carbon permissible in the charge; (2) when it is not necessary to limit the carbon

to 6 per cent., fluxing materials can be charged, giving a more fluid slag and resulting in better separation of slag from metal. There is no difficulty in obtaining a recovery of 90 to 95 per cent. of the chromium when making 8-per cent. carbon product, while the recovery on the 6-per

TABLE 4.—*Production of Ferrochrome with 4 to 6 Per Cent. Carbon*

	11	12	13	14	15	16	17	18	19	20	Average
Charge:											
Ore, lb.....	16,473	14,331	13,226	15,079	15,232	16,572	18,666	20,468	18,768	19,482	
Coke, lb.....	4,215	3,661	3,434	3,843	3,941	3,921	3,996	4,214	4,304	4,275	
Lime, lb.....	452	390	360	390	424	230	180	29			
Sand, lb.....	1,130	975	900	892	1,383	1,834	1,932	2,270	2,000	2,120	
Slag, 16% Cr., lb.....	2,907	2,529	2,334	2,661	2,688	2,924	3,294	3,612	3,282	3,438	
Ferrochrome:											
Chromium, %.....	64.0	62.8	64.1	62.2	63.2	64.60	61.0	59.8	59.8	62.0	62.37
Carbon, %.....	5.60	5.16	5.34	5.28	5.67	5.81	5.50	5.55	5.70	5.68	5.53
Slag:											
Chromium, %.....	15.70	11.65	12.77	7.65	14.84	8.45	15.77	13.5	13.82	17.15	13.13
Carbon charged per 100 lb. chrome ore, lb.....	14.6	14.6	14.8	14.5	14.7	13.6	12.2	11.8	13.2	12.5	13.3
Weight ferrochrome, lb.....	5,909	5,102	5,574	5,291	5,983	7,765	6,877	7,509	6,801	7,925	
Weight chromium, lb.....	3,799	3,208	3,560	3,292	3,768	5,020	4,180	4,497	4,061	4,932	
Weight slag, lb.....	10,325	8,610	8,505	9,688	10,200	10,333	10,904	12,967	11,567	12,703	
Chromium recovered, %.....	68.5	66.6	80.2	65.5	72.5	104.5	71.4	69.0	67.0	76.5	74.15
Kw.-hr. per lb. alloy.....	3.6	4.0	3.6	4.0	3.4	2.7	3.2	3.1	3.4	2.8	3.38

Note.—Recovery is based on metal output, and ore and slag charged. The operations were conducted in one 450-kw. furnace and one 750-kw. furnace.

cent. carbon grade varies from 70 to 80 per cent. Within limits, the grade of ore smelted has no appreciable effect on the recovery when 8-per cent. carbon product is being made.

As shown in Table 3, ore containing from 42.25 to 51.40 per cent. Cr_2O_3 was smelted with no appreciable difference in recovery. With

a drop to 35 per cent. Cr_2O_3 , appreciable loss occurs, owing to the greater volume of slag, the latter averaging about the same in chromium as that from the higher-grade ore. These same conditions exist when producing ferrochrome, with 6 per cent. carbon as shown in Table 4,

TABLE 5.—*Production of Ferrochrome, with Natural Slag*

	21	22	23	24	25	26	27	28	29	Average
Charge:										
Ore, lb.....	14,025	11,050	8,500	14,153	13,655	13,430	12,714	15,300	13,388	
Coke, lb.....	4,045	3,268	2,000	3,646	3,514	3,504	3,442	3,600	3,897	
Slag, 12% Cr, lb.....	3,175	1,950	1,500	3,836	3,749	3,999	3,894	2,700	2,363	
Ferrochrome:										
Chromium, %.....	63.60	58.30	62.1	66.22	67.10	67.20	64.7	61.0	61.20	63.49
Carbon, %.....	5.50	6.33	5.08	5.60	5.48	5.22	6.73	5.13	5.20	5.58
Slag:										
Chromium, %.....	13.41	8.50	10.23	7.0	5.4	7.17	7.17	7.90	10.26	8.56
Carbon charged per 100 lb. chrome ore, lb.....	16.4	16.9	24.2	14.7	14.6	14.8	15.4	13.4	16.8	16.3
Weight ferrochrome, lb.....	5,791	4,390	2,985	5,499	6,150	6,169	5,067	4,533	5,366	
Weight chromium, lb.....	3,669	2,553	1,844	3,648	4,103	4,121	3,266	2,870	3,273	
Weight slag, lb.....	7,228	.....	.....	7,440	7,027	6,120	4,799	.....	8,382	
Chromium recovered, %.....	78.0	64.6	69.2	64.5	84.4	89.5	73.3	59.7	74.5	73.0
Kw.-hr. per lb. alloy.....	3.63	3.42	4.09	4.18	3.58	4.06	4.74	3.32	3.54	3.9

Analyses of Natural Slags

	%	%	%
Cr_2O_3	8.80	13.08	11.91
SiO_2	22.10	23.20	21.68
FeO.....	7.71	7.71	3.47
Al_2O_3	34.80	35.50	41.20
CaO.....	5.70	2.30	4.40
MgO.....	23.18	20.28	20.79

Note.—Recovery is based on metal output, and ore and slag charged. The operations were conducted in three 150-kw. furnaces and three 250-kw. furnaces.

where the ore varied from 34 to 48 per cent. Cr_2O_3 . Future operation on nothing but 35-per cent. ore may alter this conclusion.

The addition of lime to the charge unquestionably results in a higher recovery, but increases the carbon content of the alloy. As little as

$\frac{1}{4}$ lb. lime per 100 lb. ore may increase the carbon in the product from 6 per cent. to 7 per cent., charging the same amount of carbon. The recovery, however, is considerably increased, owing to the more fluid

TABLE 6.—*Production of Ferrochrome with Silica Slag*

Charge:	30	31	32	33	34	35	36	37	38	Average
Ore, lb.....	51,395	59,330	41,888	40,532	57,902	64,924	43,928	73,814	39,086	
Coke, lb.....	13,253	15,213	10,800	10,359	12,514	14,268	9,914	16,552	10,025	
Lime, lb.....	1,437	1,618	(a) 604	1,065	209	1,321	273	81	1,349	
Sand, lb.....	4,928	3,945	2,316	2,810	6,202	7,214	4,297	8,088	4,342	
Slag (16% Cr), lb.....	9,099	8,670	7,822	7,408	10,188	11,467	7,752	12,728	7,074	
Carbon, lb. per 100 lb. chromite	14.8	14.6	14.7	14.6	12.4	12.6	12.9	12.8	14.6	
Analysis ore: Cr ₂ O ₃ , %.....	42.15	44.95	44.95	42.15	41.74	41.74	43.96	43.96	42.15	
FeO, %.....	11.27	11.80	11.80	11.27	11.00	11.00	.....	.....	11.27	
Al ₂ O ₃ , %.....	19.70	19.70	.....	.....	.....	.....	.....	.....	.....	
MgO, %.....	15.50	15.50	.....	.....	.....	.....	.....	.....	.....	
SiO ₂ , %.....	8.52	5.80	5.80	8.52	12.46	12.46	9.40	9.40	8.52	
S, %.....	0.03	0.03	0.03	.....	.....	.....	.....	.....	.....	
P, %.....	0.024	0.024	0.024	.....	.....	.....	.....	.....	.....	
Cu, %.....	0.004	0.004	0.004	.....	.....	.....	.....	.....	.....	
Ferrochrome: Cr, %.....	62.02	63.82	63.45	62.01	59.78	64.95	58.55	59.50	64.5	62.06
C, %.....	6.17	5.83	5.73	5.69	5.98	6.36	5.93	5.37	5.80	5.87
Si, %.....	2.17	1.50	2.07	0.95	1.06	2.83	1.99	1.66	1.48	1.85
S, %.....	0.09	0.09	0.057	0.041	0.044	0.018	.....	0.014	0.038	0.050
Analysis slag: Cr ₂ O ₃ , %.....	26.63	19.00	20.00	17.52	19.65	18.60	20.00	20.34	21.60	
Al ₂ O ₃ , %.....	38.20	36.00	.....	.....	.....	.....	.....	.....	.....	
FeO, %.....	8.53	8.74	.....	.....	.....	.....	7.45	.....	.....	
SiO ₂ , %.....	15.00	17.50	17.64	21.2	26.16	26.20	27.70	28.62	30.00	
CaO, %.....	1.00	1.00	1.00	.....	.....	.....	.....	.....	.....	
MgO, %.....	15.00	18.25	.....	.....	.....	.....	.....	.....	.....	
Chromium lost in slag, %.....	38.25	24.00	24.70	27.00	25.8	25.7	26.8	24.5	32.60	27.71
Chromium recovered, %.....	61.75	76.00	75.30	73.00	74.2	74.3	73.2	75.5	67.4	72.29
Chromium actually tapped, %.....	71.10	68.37	74.80	70.00	69.1	83.3	64.8	62.8	75.06	71.02

(a) Test No. 32 contained also 116 lb. fluorspar.

(b) Calculated from slag loss.

slag and smaller loss of metallics in the slag. Fluorspar has the same effect as lime.

When operating with a natural slag, i.e., slag produced from the natural constituents of the ore and the ash of the coke, a 6-per cent. carbon product can be made easily, but the loss of metallics is high with most domestic ores, owing to the thick, sticky slag formed. However, some

ores, higher than usual in silica, run very well. Results of operation with a natural slag are shown in Table 5.

On the whole, when producing ferrochrome with 6 per cent. carbon, a small quantity of silica and lime make the most satisfactory flux, if any flux is necessary. The recovery is a little higher than where running with a natural slag, and the presence of silica in slight excess tends to throw carbon and sulphur out of the alloy. Ferrochrome sometimes contains over 2 per cent. silicon when sand is charged, but this is not objectionable. Results of operation with sand are given in Table 6, showing analyses of the slags, the grade of alloy, and the recovery of chromium. The coke contained 57.0 per cent. fixed carbon, 37.9 per cent. ash, 5.27 per cent. volatile matter, and 0.51 per cent. sulphur. The lime analyzed 85 per cent. CaO, and the fluorspar 82 per cent. CaF_2 .

The tests given in Tables 3 and 4 were selected at random. When making 8-per cent. carbon product, the slags average 5.21 per cent. chromium as against 13.13 per cent. chromium when producing 6-per cent. carbon material, a difference of 7.92 per cent. The chromium recovery on ferrochrome of 8-per cent. carbon is 94.07 per cent., in comparison with 74.15 per cent. when producing material, containing 6 per cent. carbon, or 19.92 per cent. higher recovery. The effect of a greater amount of carbon in the charge is shown clearly. In Table 3, 17.3 lb. carbon was charged per 100 lb. of chromite, resulting in a recovery of 94.07 per cent. In Table 4, only 13.13 lb. carbon was charged per 100 lb. of chromite, giving a recovery of 74.15 per cent. The ore averaged 44 per cent. chromium.

Ferrochrome containing 6 per cent. carbon can be made easily by using a natural slag. The chromium content of such slag is 8.56 per cent. (Table 5), while, when using lime and silica, the slag contained 13.13 per cent., and with silica alone as a flux (Table 6) it varied from 17.5 to 26.6 per cent. chromic oxide (12 to 18.2 per cent. chromium). In the three cases, the actual chromium tapped was respectively 73.0, 74.15, and 71.02 per cent. The combination of lime and silica thus shows a little higher recovery; generally, however, if the slag will run, it is advisable to use a natural slag. When the alumina is about 35 per cent. and the silica 20 to 25 per cent., these slags are very fluid, but at times retain metallics. The use of a large quantity of silica does not improve the recovery, as shown in Table 6, but it does have a marked effect on the sulphur content of the alloy.

Smelting of Low-grade Ore or Chrome Slag

There has been considerable discussion as to how low-grade chrome ore can be used in manufacture of ferrochrome. In Table 7, results of smelting chrome slag are given. On slags containing from 13.9 to 36.25 per cent. Cr_2O_3 , average 24.37 per cent., an average recovery of 80.2

TABLE 7.—*Smelting Chromium Slag.*

	39	40	41	42	43	44	Average
Charge:							
Slag, lb.....	17,170	13,770	15,470	14,750	18,000	15,600	
Coke, lb.....	2,912	2,340	2,762	1,311	1,472	1,264	
Sand, lb.....	1,060	824	930	375	456	398	
Percentage Cr_2O_3 in slag smelted.....	36.25	31.50	26.10	23.4	13.90	15.10	24.37
Ferrochrome:							
Chromium, %	62.25	61.60	61.60	63.05	60.50	59.05	61.34
Carbon, %	6.55	6.50	6.47	8.12	6.37	6.47	6.81
Slag:							
Chromium, %	9.05	11.70	3.05	3.20	5.70	3.10	5.96
Weight ferrochrome, lb.....	5,385	3,270	3,995	3,362	2,031	2,323	
Weight chromium, lb.....	3,340	2,002	2,460	2,122	1,228	1,372	
Weight slag, lb.....	10,119	8,328	10,577	7,702	8,018	7,563	
Chromium recovered, %.....	78.6	67.2	88.6	89.4	72.3	85.3	80.2
Kw.-hr. per lb. alloy.....	2.8	4.0	3.3	3.7	6.4	5.7	4.3

per cent. was made, with the production of metal containing an average of 61.34 per cent. chromium, 6.81 per cent. carbon, 0.063 per cent. sulphur, and 2.5 per cent. silicon. Even with a very low-grade slag, 15 per cent. Cr_2O_3 , a recovery of 85 per cent. was made. The cost of actual operation was not much greater than when smelting ore, but including interest and depreciation charges, the total cost would be considerably higher because of the small output of metal for the power consumed.

From these results, it seems reasonable to expect that a good recovery could be made from ore containing 25 per cent. Cr_2O_3 , if the product were allowed to contain 7 per cent. carbon.

Grade of Ferrochrome Made from Domestic Ore

Ferrochrome made from domestic chrome ore ranges from 60 to 67 per cent. chromium, as compared with 65 to 70 per cent. chromium in ferrochrome made from imported ore. The lower chromium content is due to the higher percentage of iron in domestic ore, and also probably, to a less degree, to the larger volume of slag, and consequent greater loss of chromium. Aside from the chromium content, the carbon and other impurities are as low as in ferrochrome made from foreign ore. In Table 8, analyses of ferrochrome made from domestic ores are given, the analyses covering material from 1 ton to a carload in quantity.

Use of 60 to 65-Per Cent. Ferrochrome Instead of 65 to 70-Per Cent. in Steel Manufacture

In general, it may be stated that ferrochrome containing 60 to 65 per cent. chromium is not undesirable in the steel industry by reason of

its lower chromium and high carbon content. In the first place, its carbon content need be no higher than that of an alloy containing 65 to 70 per cent. chromium. That is, the carbon in both products can readily be kept under 6 per cent., but, of course, if the standard is maintained at 6 per cent. a larger amount of carbon is present per pound of chromium in the case of the 60 to 65-per cent. ferrochrome. If a user would specify 60 to 65-per cent. ferrochrome and 5.5 instead of 6 per cent. carbon, the

TABLE 8.—*Ferrochrome Made From Domestic Ore*

	Carbon 1% Maximum	Carbon 2% Maximum	Carbon 5% Maximum	Carbon 6% Maximum	Carbon 7% Maximum	Carbon 8% Maximum
Carbon.....	0.75	1.83	4.75	5.52	7.00	7.67
Chromium.....	67.20	62.10	63.40	65.00	66.00	66.40
Silicon.....	0.42	0.40	0.17	0.47	0.93	0.86
Manganese.....		0.24	0.25	0.29	0.24	0.27
Sulphur.....	0.052	0.056	0.082	0.078	0.055	0.056
Phosphorus.....	0.065	0.047	0.045	0.036	0.035	0.036

ratio of chromium to carbon would be the same as in the alloy containing 65 to 70 per cent. chromium and 6 per cent. carbon, and no more carbon would be added to the steel bath by the low-grade than by the high-grade alloy. The carbon content of ferrochrome depends considerably upon the amount of chromium present, which combines with the carbon to form carbides; also upon the amount of silicon present. In the lower-chromium alloy, there should therefore be less carbon than in the high-chromium alloy. It is entirely feasible to make 60 to 65-per cent. ferrochrome with a maximum of 5.5 per cent. carbon. The silicon content, if allowed to increase a little above 1 per cent., also tends to throw the carbon out of the alloy.

Ferrochrome with 67.5 per cent. chromium and 6 per cent. carbon contains 0.088 lb. of carbon per pound of chromium; ferrochrome with 62.5 per cent. chromium and 6 per cent. carbon contains 0.096 lb. of carbon per pound of chromium. The 62.5-per cent. alloy, in order to contain the same amount of carbon per pound of chromium as the 67.5-per cent. alloy with 6 per cent. carbon, should contain 5.5 per cent. carbon. The use of ferrochrome containing 62.5 per cent. chromium and 6 per cent. carbon, in ordinary chrome-vanadium steel, which contains 1 per cent. chromium, will increase the carbon content of the steel above that when the 67.5-per cent. alloy is used, to the extent computed below.

One hundred pounds of 1-per cent. chromium steel will require the addition of approximately 1.48 lb. of 67.5-per cent. ferrochrome; or approximately 1.6 lb. of 62.5-per cent. ferrochrome. The amount of carbon added to 100 lb. of the steel by the use of the 67.5-per cent.

ferrochrome is 1.48×6 per cent. = 0.088 lb. The amount of carbon added by the use of the 62.5 per cent. alloy is 1.6×6 per cent. = 0.096 lb. The use of the lower-grade ferrochrome will thus increase the carbon in a 1-per cent. chromium steel by approximately 0.008 per cent. Or, for example, if a chrome-vanadium steel, made from 67.5-per cent. ferrochrome, contains 0.4 per cent. carbon, 0.15 per cent. vanadium, and 1 per cent. chromium, it would contain, if made from 62.5-per cent. ferrochrome, approximately 0.408 per cent. carbon. No allowance is made for loss of chromium in the addition of the ferrochrome.

It can safely be stated that the use of 60 to 65-per cent. alloy will not increase the carbon in chrome-vanadium by over 0.01 per cent. Also, if

TABLE 9.—*Raw Materials for Making Ferromanganese*

Anthracite		Limestone		Fluorspar	
	%		%		%
Fixed carbon.....	82.76	CaO.....	54.56	CaF ₂	81.8
Ash.....	10.20	SiO ₂	0.18		
Volatile.....	7.04	MgO.....	0.25		
Sulphur.....	0.84				

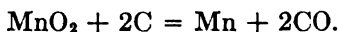
TABLE 10.—*Domestic Manganese Ore from Colorado, Utah, and Nevada*

	Homansville, Utah				Las Vegas, Nev.				Montrose, Colo.	
	%	%	%	%	%	%	%	%	%	%
Mn.....	39.17	40.62	37.52	37.47	40.37	39.62	38.47	38.75	43.58	44.67
SiO ₂	12.21	11.52	13.02	11.69	13.55	14.16	15.18	15.26	6.58	6.76
Fe.....	1.35	1.20	1.30	1.15	0.85	0.75	0.70	.....	4.17	2.79
CaO.....	.....	5.78	.....	7.65	.....	.....	.....	.....	.....	.....
P.....	0.285	0.228	0.329	0.351	0.022	0.023	0.023	0.024	0.55	0.145
H ₂ O.....	16.1	14.5	15.5	14.8	8.35	9.15	14.16	14.6	.....	8.30

a 62.5-per cent. alloy containing 5.5 per cent. carbon were used, the steel would contain the same amount of carbon (0.4 per cent.) as if the higher-chromium alloy were used.

FERROMANGANESE

The preparation of ferromanganese in the electric furnace consists in charging a proper mixture of ore, coal, and limestone in proper proportions for the reduction of manganese with a minimum slag loss. The furnace operates at 75 to 100 volts. With dioxide ores reduction takes place according to the reaction:



Iron is added either as a constituent of the ore or in the form of iron

turnings. The power consumption varies from 4000 kw.-hr. per long ton in a 3000-kw. furnace to 7000 kw.-hr. per long ton in a 1000-kw. furnace. The electrode consumption is high, ranging from 150 to 250 lb. per long ton of product, when using amorphous carbon electrodes.

TABLE 11.—*Smelting Domestic Manganese Ore in the Electric Furnace*

	1	2	3	4	5	6	7	8	9	10	Average
Charge:											
Manganese ore, lb.....	16,000	18,400	21,600	18,099	17,700	17,700	20,000	21,322	17,500	16,700	
Coal, lb.....	4,140	4,600	5,950	4,460	4,400	4,400	4,840	5,280	4,400	3,980	
Limestone, lb.....	5,850	6,500	8,450	6,500	7,300	6,500	7,075	7,375	6,000	5,400	
Iron turnings, lb.....	1,125	1,250	1,550	900	825	600	660	600	600	540	
Carbon per 100 lb. ore..	25.8	25.0	27.6	24.7	25.8	25.8	24.2	24.7	25.2	23.8	
Manganese in ore, %....	39.3	39.9	38.7	39.50	39.5	39.25	39.0	38.6	37.8	37.8	38.93
Ferromanganese:											
Manganese, %.....	76.4	75.6	78.53	79.25	79.46	80.15	80.65	80.5	81.46	81.4	79.34
Silicon, %.....	1.5	1.1	1.34	0.91	0.47	1.26	0.12	1.29	2.57	1.50	1.20
Phosphorus, %.....	0.227	0.210	0.173	0.183	0.203	0.205	0.220	0.207	0.198	0.203	0.202
Sulphur, %.....		0.005	0.015	0.030	0.013	0.017	0.004	0.017	0.035	0.024	0.018
Slag:											
Manganese, %.....	12.58	15.38	9.08	12.88	16.18	13.78	14.97	11.56	12.05	10.95	12.94
SiO ₂ , %.....	28.84	27.36	28.74	27.90	25.64	27.54	22.74	28.96	29.52	30.72	27.79
CaO, %.....	38.06	33.22	30.51	35.03	35.48	37.25	33.95	37.49	35.96	37.09	35.40
MgO, %.....			9.02			2.60					5.81
Al ₂ O ₃ , %.....			8.90			9.16					9.03
Wt. ferromanganese, lb..	6,785	6,552	7,674	6,502	7,823	6,089	6,937	7,564	5,420	6,865	6,821
Weight slag, lb.....	10,556	9,221	11,043	8,537	10,903	8,190	10,341	9,145	8,353	9,753	9,604
Manganese lost in slag, %	20.7	19.3	11.9	15.5	25.2	16.2	19.8	12.8	15.5	16.8	17.3
Manganese lost by volatilization and dust, %..											
Manganese recovery, %..		10.2	16.9	12.1		13.8	8.7	13.6	17.3		7.3
Kw.-hr. per long ton ferromanganese.....	6,400	7,150	5,980	6,220	6,320	6,600	6,420	6,400	6,450	7,350	75.4

Analyses of some domestic manganese ores produced in Colorado, Utah, and Nevada are given in Table 10. Some of this ore is so high in phosphorus that it has to be mixed with the low-phosphorus ore to yield a product under 0.2 per cent. phosphorus. Most of these ores are very dusty, resulting in a heavy dust loss, even in the electric furnace.

Smelting Domestic Manganese Ore in the Electric Furnace

Table 11 gives results from the electric smelting of the ores given in Table 10, and the other materials shown in Table 9. These results are based on the first month's operation of a 1200-kw. furnace, and do not represent what is being done by the same furnace at the present time, when a considerably better recovery is being made with a lower power consumption.

Smelting an ore averaging 38.9 per cent. manganese and 13.0 per cent. SiO_2 , the recovery in metal tapped is 75.4 per cent., with an average loss of 17.3 per cent. in the slag and 7.3 per cent. mechanically and by volatilization. Considerably better results are now being obtained, especially as regards slag loss. The power consumption was 6429 kw.-hr. per long ton of ferromanganese, measured on the primary side of the transformers. The average metal produced contained: manganese, 79.34; silicon, 1.2; phosphorus, 0.202; sulphur, 0.018 per cent. The quantity of coal charged was less than 10 per cent. above the theoretical amount required for complete reduction, which is contrary to the practice at several electric-furnace plants.

FERROMOLYBDENUM

The use of ferromolybdenum in the metallurgy of steel is in its infancy. Previous to 1914, probably not over 10 tons was produced yearly in the United States, practically all of this being exported; but with the high price of tungsten, search for molybdenum ores became more active, and now several hundred tons per year are made in this country, practically all of which is exported. The alloy has not been widely used because of the supposed scarcity of ore, and the prejudices of American steel manufacturers against it, owing to difficulties encountered in its use in steel. The scarcity of ore has been overcome, and at present Colorado is the largest producer of molybdenum in the world. The prejudices of American steel manufacturers have not, however, been overcome.

Ferromolybdenum was made from roasted molybdenite in the crucible before the introduction of the electric furnace, but can now be made directly from raw sulphide in the electric furnace. Another source of molybdenum is lead molybdate, wulfenite, which is fused with soda ash and carbon to produce lead bullion and sodium molybdate slag. The slag is then smelted in the electric furnace, with carbon as a reducing agent, and suitable fluxes, to produce ferromolybdenum.

The standard grade of ferromolybdenum is not well established. Some manufacturers make a product containing 50 to 80 per cent. molybdenum and 3 per cent. carbon and manage to sell it. Others, by different methods, make a product containing less than 1 per cent. carbon. A great deal of ferromolybdenum containing 0.25 per cent. sul-

phur has been sold but most consumers will not accept a product containing over 0.1 per cent. sulphur. Ferromolybdenum containing 80 per cent. molybdenum has a dull gray iron color, coarse structure, high density, and is non-magnetic. It does not break easily.

Production of Ferromolybdenum in the Electric Furnace

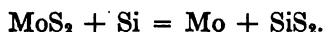
Raw materials used in preparation of ferromolybdenum may be: for ore, the sulphide, molybdenite, or sodium molybdate slag made from wulfenite; for reducing agent, some form of carbon, or 90-per cent. silicon metal ground to pass 60 mesh; for fluxes, lime and fluorspar. There are two methods of manufacture:

1. Reduction with carbon and excess of lime, according to the reaction:



Pure molybdenite contains 60 per cent. molybdenum and 40 per cent. sulphur. According to the above reaction, 100 parts of molybdenum are reduced from 170 parts of molybdenite by 18.8 parts of carbon. For every 100 parts of molybdenum, 58 parts of lime are necessary for slagging the sulphur as calcium sulphide. This reaction works out closely to the theoretical, and there is no difficulty in making a product with about 0.1 per cent. sulphur; the product will contain 1.3 to 3 per cent. carbon. If a lower-carbon alloy is desired, the crude metal is broken up and refined with an oxidizing slag of iron ore. The amount of iron in the alloy is varied as desired by the addition of iron turnings in the smelting furnace, or of iron oxide in the refining furnace.

2. Reduction with silicon metal, according to the reaction:



This method has been used recently in the production of 50-per cent. ferromolybdenum, although when this grade is being made, ferrosilicon may be used. Lime is sometimes added to help slag the sulphur as calcium sulphide. By this method, the production of 100 parts of molybdenum requires 29 parts of silicon.

When sodium molybdate slag is the source of molybdenum, reduction takes place according to the reaction:



The use of sodium molybdate requires considerably more power than the other reactions, because very little reduction occurs until all free soda salts which may be in the slag are driven off. The regular grade of sodium molybdate slag used for this purpose contains 30 to 40 per cent. MoO_3 . In all electric-furnace work, the presence of sodium salts interferes with the speed of the reactions.

The average wulfenite¹ from which ferromolybdenum is produced

¹ Alan Kissock, Manager, Molybdenum Products Co., Tucson, Arizona; personal correspondence.

contains: MoO_3 , 16; lead, 50; SiO_2 , 6; FeO , 11.0; CaO , 2.0; arsenic, 0.8; phosphorus, 0.05 per cent. This concentrate is smelted in a circular, water-jacketed lead blast furnace with coke and soda ash to produce lead bullion and molybdenum slag. The slag contains: MoO_3 , 33; lead, 1.0; SiO_2 , 11 to 14; FeO , 17; CaO , 7; arsenic, 1.0; phosphorus, 0.1 per cent.; remainder, soda. This molybdenum slag, crushed to about $\frac{1}{2}$ in., is smelted in single-phase electric furnaces of the Siemens type, lined with magnesite, to produce ferromolybdenum. The charge is calculated to a monosilicate slag, using lime as a flux. Iron ore is added to produce an alloy containing 60 to 65 per cent. molybdenum, and residues from an oil-gas plant are used for reducing agent.

The average power consumption is 7 to 7.5 kw.-hr. per pound of molybdenum produced. The recovery varies from 78 to 80 per cent., with a loss of 10 per cent. in slag, and about 10 per cent. mechanically and by volatilization.

TABLE 12.—*Ferromolybdenum Made from Sodium Molybdate Slag*

Molybdenum, %	61.0	62.34	66.96	64.78	62.35	62.92
Carbon, %	2.31	2.214	2.03	1.51	1.91	1.29
Silicon, %	0.41					
Phosphorus, %	0.086	0.018	0.029	0.018	0.040	0.13
Sulphur, %	0.098	0.075	0.060	0.022	0.049	0.030
Arsenic, %	1.10					
Copper, %	0.018					
Manganese, %	0.2					

Ferromolybdenum containing 80 per cent. molybdenum and under 1 per cent. carbon cannot be regularly tapped from the electric furnace because of its high melting point, so that when this grade of alloy is to be made, the furnace must be of the knock-down variety, for removal of the button. The slag is tapped off, and when this operation is finished the metal is dug out. A 50 to 60-per cent., low-carbon product can be tapped, and a considerable quantity of this grade is made in tapping furnaces.

Molybdenum in Steel Manufacture

Ferromolybdenum is added to steel as a fixed addition, nearly all of the molybdenum remaining in the steel. It is supposed to give the steel properties similar to those of tungsten steel, but only one-third to one-half as much molybdenum is necessary; that is, where regular high-speed steel contains 18 per cent. tungsten, 6 to 9 per cent. of molybdenum may be substituted. However, it gives these properties only when the addition is properly made and proper heat treatment follows. The regulation of these factors caused so much trouble and expense that, in this country, the manufacture of molybdenum high-speed tool steels

has been practically discontinued for several years. It is used for this purpose abroad, however, to a considerable extent. At the present time, it is mainly employed in tool steel as an auxiliary rather than as a major constituent.

Various reasons have been assigned for the discontinuance of the use of molybdenum in these steels. Taylor found that molybdenum in rapid steels caused irregular performance; that steels of the same composition and having had seemingly the same treatment gave large variations in their maximum cutting speeds. One manufacturer has stated that the ingots crack in forging, the tools crack on quenching, and molybdenum appears to volatilize from the steel when heated; the latter might be due to the production of molybdenum oxide, which is much more volatile than the metal itself.

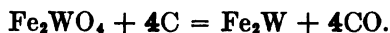
When small quantities of molybdenum, say 0.25 per cent., are added, the elongation and elastic limit of the steel are greatly increased. When molybdenum is combined with nickel, the resistance to shock is increased without diminishing the elongation. Its utilization for linings of big guns was originated by the Germans, with such success that the Allies are said to use it now for the same purpose. This may account for the heavy exports of molybdenum.

FERROTUNGSTEN

Tungsten is the leading alloy metal used in the manufacture of high-speed steel. Probably about half of the consumption is used in the form of ferrotungsten, the remainder being tungsten metal. Colorado has supplied a large part of the tungsten used in steel manufacture, but is gradually being surpassed by California, where the large scheelite deposits can produce tungsten considerably cheaper. Ferberite, found in Boulder County, Colo., is one of the most favorable forms of tungsten for production of ferrotungsten, containing both iron and tungsten in the proper proportion to yield 70 to 80 per cent. ferrotungsten. At present, three electric-furnace plants in Colorado are making or have made ferrotungsten. The standard grade produced by the Ferro Alloy Co. contains 75 per cent. tungsten, 0.8 carbon, 0.4 silicon, 0.5 manganese, 0.01 sulphur, 0.02 per cent. phosphorus. The Tungsten Products Co. makes about the same grade of product, except that the carbon is kept below 0.5 per cent., and the tungsten runs as high as 85 per cent. The product of this company is probably the highest-grade and the purest ferrotungsten made in this country. Ferrotungsten has a high density, fine gray fracture, and is not crystalline—the higher the carbon, the coarser the fracture. The carbon in ferrotungsten occurs as the double carbide, $\text{Fe}_3\text{C.W}_2\text{C}$.

One method commonly employed for production of ferrotungsten is reduction of ferberite or some other concentrate in the electric furnace,

with carbon as a reducing agent, followed by a subsequent refining and decarburization. Reduction with carbon takes place according to the following reaction:



Theoretically, the product would contain 62.3 per cent. tungsten, but, owing to the variation in iron in the ferberite, and to the fact that tungsten reduces from ferberite, in the electric furnace, before the iron comes down, a considerable part of the iron passes into the slag, so that the alloy contains about 70 per cent. tungsten. The slag may contain as high as 8 per cent. FeO , but less than 1 per cent. WO_3 . Theoretically, the reduction of 100 parts of alloy from 122 parts of ferberite requires 16 parts of carbon, but practically about 25 per cent. excess of carbon is charged. Small amounts of lime and fluorspar are used to flux the silica. Operating in this manner, with an excess of carbon, a product is made containing 3 per cent. carbon, 70 per cent. tungsten, 0.05 per cent. phosphorus, and 0.01 per cent. sulphur; the slag contains below 1 per cent. WO_3 . If desired, this product can be tapped from the furnace, but, as its behavior is erratic, it is preferable to allow the metal to collect in the bottom of the furnace, forming, in a 150-kw. furnace, a button about 3 ft. in diameter, 6 in. thick, and weighing 1000 to 1200 lb.; the slag is poured off by tilting as it fills the furnace.

The concentrate used in the runs given in Tables 13 and 14 contained WO_3 , 60.36 per cent.; iron, 22.0; SiO_2 , 8.0; manganese, 0.5; sulphur, 0.35; phosphorus, 0.05 per cent. The analysis of the coke was: fixed carbon, 81.8; volatile, 1.70; ash, 16.5; sulphur, 0.60; phosphorus, 0.092 per cent. The lime contained: CaO , 89.0; MgO , 0.73; SiO_2 , 1.1; sulphur, 0.41; phosphorous, 0.072 per cent. The fluorspar contained 80.0 per cent. CaF_2 .

Smelting of Ferberite Concentrate

A typical operation is conducted as follows: The initial charge is 65 lb. of a mixture composed of 200 lb. concentrate, 42 lb. coke, 56 lb. lime, 6 lb. fluorspar. Three more 35-lb. charges are added at intervals of $\frac{1}{2}$ hr., and at $2\frac{1}{2}$ hr. from the start, the furnace is tilted and the slag poured. This cycle is repeated until a 1200-lb. button has been formed, requiring 24 to 36 hr. The furnace is allowed to cool, is torn down, and the button of metal removed. This is then cleaned and broken up, the breaking process being somewhat difficult with a 3-per cent. carbon alloy.

The results of smelting ferberite concentrate to produce a crude ferrotungsten are given in Table 13. In this operation there is practically no loss of tungsten in the slag, the slags averaging 0.72 per cent. tungsten. Considerable mechanical loss is shown in these runs, but this occurs mainly in dust, when cleaning and breaking the button, and is

recovered by melting. The total loss of tungsten in the smelting operation does not exceed 5 per cent.

TABLE 13.—*Smelting of Ferberite Concentrate*

	1	2	3	4	5	6	7	8
Charge:								
Concentrate, lb.....	1,200	1,800	1,600	1,600	2,275	3,150	2,950	3,100
Coke, lb.....	252	380	330	330	476	662	662	648
Fluorspar, lb.....	96	180	128	130	62	96	90	120
Lime, lb.....	336	500	436	436	628	872	810	855
Ferrotungsten:								
Tungsten, %.....	71.71	{ 71.35 68.3	67.9	68.2				
Carbon, %.....	1.01	{ 2.6 1.7	1.03	1.09				
Sulphur, %.....	0.078	0.10	0.048	0.068				
Phosphorus, %.....	0.081	0.112	0.065	0.11				
Slag:								
Tungsten, %.....	0.56	0.80	0.90	1.26	0.20	0.88	0.35	0.39
Weight ferrotungsten, in button, lb.....	731	982	847	908	954	1,884	1,490	1,971
Weight ferrotungsten, poured, lb.....		122						
Weight, slag, lb.....	588	1,020	510	1,121	1,960	1,612	1,200	2,613
Length run, hr.....	19.33	26.17	20.17	22.0	36.0	40.5	44.0	48.0
Power on, hr.....	17.33	21.08	18.0	19.42	34.83	38.83	42.5	46.33
Tungsten lost in slag, %.....	0.57	0.95	0.63	1.96	0.36	0.94	0.29	0.66
Tungsten lost mechanically, % (a).....	10.23	11.65	19.37	11.84				
Tungsten recovered, %.....	89.2	87.4	80.0	86.2				

(a) Most of this is recovered in dust.

Note.—The current consumption was 130 kw. at 95 volts.

Refining Ferrotungsten

The crude metal, broken to about 6 in. size, is refined as follows: A charge of 150 lb. metal and 75 lb. ferberite concentrate is smelted for $\frac{1}{2}$ hr., when 12 lb. fluorspar is added. After another 3 hr. the slag is poured, and a fresh charge is started. The process is continued for from 36 to 48 hr. until a button weighing 1500 lb. has formed in the furnace, a larger button being permissible because the low-carbon alloy is easier to break. The furnace is allowed to cool, is torn down, and the button of metal removed, cleaned, and broken. The refined button forms very compactly, and is free from slag. The refining has reduced the carbon from 3 to 0.8 per cent., reduced the phosphorus from 0.05 to 0.01 per cent., left the sulphur the same, and increased the tungsten from 70 to 75 per cent. The refining slag contains 5 to 20 per cent. tungsten, and is resmelted in a special run.

Table 14 gives data on the refining of crude ferrotungsten containing 2 to 3 per cent. carbon, to yield a product with less than 1 per cent. carbon.

TABLE 14.—*Refining Ferrotungsten*

	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Charge:														
Ferrotungsten, lb.....	1,400	1,200	800	1,835	1,680	1,160	1,190	1,050	1,200	1,200	1,200	1,200	1,350	1,500
Tungsten concentrate, lb.....	448	480	320	720	674	462	476	420	520	670	600	675	750	825
Fluorspar, lb.....	140	120	80	180	141	96	96	84	96	108	96	10	108	120
Ferrotungsten:														
Carbon, in button, %.....	0.84	0.88	0.90	0.68	0.71	0.73	0.88	0.75	0.65	0.66	0.91	0.66	0.97	0.57
Carbon, in poured, %.....	1.37	0.95	1.27	1.32	1.22	.....	.....	.....	.....	1.02	1.59	1.50	.....	0.63
Slag:														
Tungsten, %.....	5.21	5.21	5.21	5.21	9.50	17.18	.....	5.54	5.54	.....	.....	.....	.....	.....
Concentrate charged per 100 lb. ferrotungsten.....	32.00	40.00	40.00	39.25	40.25	39.75	40.20	40.0	43.4	55.8	50.0	56.3	55.6	55.0
Weight ferrotungsten in button, lb.....	939	1,232	400	1,868	1,424	814	727	913	922	1,217	1,278	1,234	1,535	1,672
Weight ferrotungsten poured, lb.....	.....	.....	720	186	335	345	70	.....	138	101	62	.....	266	107
Weight slag, lb.....	393	497	534	812	568	544	412	373	495	543	418	576	470	571
Length run, hr.....	22.66	21.33	19.5	17.33	34.83	33.75	26.0	33.5	29.5	34.5	35.33	32.33	33.75	37.33
Power on, hr.....	22.00	20.83	19.0	16.17	33.83	32.66	25.45	31.83	28.75	33.33	34.5	31.5	33.0	30.5

Note.—The power consumption was 130 kw. at 95 volta.

During these runs a considerable quantity of ferrotungsten was poured from the furnace with the slag. While the metal obtained in button form contained less than 0.9 per cent. carbon, the poured metal averaged

1.2 per cent. carbon. All of the slag from the refining process, averaging about 10 per cent. tungsten, is re-treated for ferrotungsten, so that there is no loss in refining, except a slag loss of less than 1 per cent., and a mechanical loss. By smelting this slag, ferrotungsten was produced which contained tungsten, 79.1; carbon, 2.40; sulphur, 0.01; phosphorus, 0.02 per cent.; the slag from this operation contained 0.95 per cent. tungsten.

Ferrotungsten is one of the easiest ferro-alloys to manufacture, except for the fact that it must be made in a knock-down furnace, due to the high melting point of the alloy, about 2500° C. Metallurgically it is simple, as tungsten has not so great a tendency to form carbides or to oxidize as have chromium and uranium. Ferrotungsten containing less than 1 per cent. carbon can be made in a single smelting operation, by careful regulation of the carbon in the charge, and the use of an acid slag. The disadvantage of this method is that the product is less pure, and the slag loss is considerably higher; the metal will contain much higher phosphorus and sulphur, and the total loss of tungsten may be 25 per cent. as compared with 10 to 15 per cent. by the two-stage process.

Nearly every manufacturer of ferrotungsten has tried to tap it from the furnace, but none has continued the practice. If the tungsten is reduced to 55 to 60 per cent., the alloy can be tapped, even with carbon as low as 0.2 per cent. With tungsten at 70 per cent., metal containing 0.9 per cent. carbon has run out while pouring slag, but generally any metal which comes out with the slag will contain 1.25 per cent. carbon. The irregularity of tapping operations with ferrotungsten has prevented the adoption of that method, because if part of the metal must be retained in the furnace, it is cheaper to keep it all there. Furthermore, the poured metal is very hard to break.

In ferrotungsten production it is essential to maintain regularity of charging, as this is the only way to insure homogeneous composition of the metal, since the button is not melted throughout. Even during refining, the metal does not melt to any extent, the action taking place while the metal is in a pasty condition. To insure a more homogeneous product, consumers require the alloy to be crushed to $\frac{1}{4}$ in., this crushing forming one of the main trials of the manufacture.

Analyses of ferrotungsten made from ferberite by smelting and refining are shown in Table 15.

TABLE 15.--*Ferrotungsten Produced from Ferberite*

	%	%	%	%	%
Tungsten.....	74.19	71.19	71.50	69.70	72.09
Carbon.....	1.00	0.99	0.88	0.99	0.96
Silicon.....	0.39	0.42	0.70	0.44	0.76
Manganese.....	0.53	0.14	0.21	0.15	0.24
Sulphur.....	0.010	0.012	0.039	0.002	0.055
Phosphorus.....	0.013	0.021	0.022	0.024	0.037

FERROVANADIUM

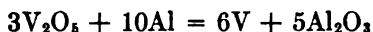
All vanadium ores require a chemical treatment to put the vanadium in the form of vanadium oxide or iron vanadate before it can be reduced to metal. The process for extraction of vanadium from Colorado roscoelite² has been described as follows:

Ore containing 1 to 3 per cent. V_2O_5 is treated. The ore is given a roast with salt and iron sulphide, leaving the vanadium in the form of sodium vanadate, which is soluble in water. The iron vanadate is added to aid in keeping a high temperature in the roaster. The roasted ore is leached with weak solution of sodium vanadate followed by hot water. Before precipitation with iron sulphate, the solution is cooled with an air jet. The iron sulphate must be present in excess, and 4 to 6 hr. are necessary for complete precipitation. Agitation with air continues for 4 to 6 hr. after precipitation to prevent precipitation of lime. The precipitate of iron vanadate is filtered in a Kelley press and washed with water. After drying, it is shipped to the alloy reduction plant.

Probably 75 per cent. of the ferrovanadium produced is made in the open-hearth or crucible furnace, by a modification of the thermit process, using aluminum as reducing agent. The remainder is produced by the electric furnace, using 90 per cent. silicon metal as reducing agent.

Standard ferrovanadium contains from 30 to 40 per cent. vanadium, and less than 0.5 per cent. carbon, 1 per cent. silicon, 2 per cent. aluminum, 0.1 per cent. sulphur, and 0.1 per cent. phosphorus. It has a fine fracture, is not crystalline, and is bright gray in color. Experience has shown that the 33-per cent. grade is best for making vanadium additions to steel. Carbon is very objectionable in ferrovanadium, because over 1 per cent. carbon causes some of the vanadium to enter the steel in the form of carbide, producing an injurious effect.

The largest output of ferrovanadium is made by reduction of vanadium oxide or iron vanadate with aluminum shot in a gas-fired open hearth, slagging off the alumina by addition of soda ash or fluorspar. If vanadium oxide is used, iron turnings are added as necessary. The process is partly exothermic, but not enough heat is produced by the reaction between the aluminum and the vanadium oxide to carry on the reduction without the application of heat. The use of iron vanadate is open to the objection that additional aluminum is required for the reduction of iron, which increases operating costs considerably at the present time. Reduction takes place according to the reaction:



In the electric-furnace process, the use of carbon as reducing agent for vanadium oxide has been generally discontinued because of the difficulty in keeping the carbon low, and the tendency to form carbides

² *Mining World* (July 17, 1915), 43, 105.

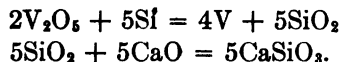
which the steel manufacturers maintain are injurious to steel. Silicon has been found the best reducing agent, aluminum volatilizing too easily and being more expensive. The raw materials for the manufacture of ferrovanadium in the electric furnace are steel turnings, vanadium oxide, silicon, lime, and fluorspar. The turnings should be low in carbon. While 90 per cent. silicon metal, ground to 60 mesh, is preferable, ferrosilicon can be used if necessary. All of these materials should be low in phosphorus. Any standard type of electric furnace can be used for making ferrovanadium, but it should be lined with magnesite.

TABLE 16.—*Electric Smelting of Vanadium Oxide*

	1	2	3	4	5	Average
Charge:						
Vanadium oxide, lb.....	396	330	462	528	528	
Steel turnings, lb.....	190	200	280	320	350	
Silicon metal, lb.....	252	210	294	333	295	
Lime, lb.....	780	670	910	980	1000	
Ferrovanadium:						
Vanadium, %.....	29.0	31.4	34.5	32.2	33.80	32.1
Silicon, %.....	3.47	3.01	3.44	6.09	4.09	4.02
Slag:						
Vanadium, %.....	0.36	0.87	0.90	2.91	0.87	1.18
V ₂ O ₅ in vanadium oxide, %.....	83.5	83.5	84.4	84.0	83.3	83.7
Silicon charged per 100 lb. vanadium oxide, lb.....	63.7	63.7	63.7	63.5	56.0	
Weight ferrovanadium, lb.....	550.5	344.0	535.0	505.0	504.5	
Vanadium recovered, %.....	86.0	70.1	83.9	66.3	70.0	75.2
Kw.-hr. per lb. ferrovanadium.....	1.7	2.9	1.9	2.0	2.0	2.1

Electric Smelting of Vanadium Oxide

Steel turnings are first charged into the furnace; when they are melted, vanadium oxide is added, followed by a mixture of silicon and lime. When the slag is fluid, in from 1 to 1½ hr., it is raked off, and more vanadium oxide charged, followed by a mixture of silicon and lime. About an hour after this the slag is pulled out and the metal tapped. Instead of pulling the slag out through a door, a separate slag tap hole may be provided. A large quantity of slag is formed in the operation because of the large quantity of lime which must be charged to combine with the silica formed by reduction of vanadium oxide with silicon. If iron vanadate is used instead of vanadium oxide, no turnings are charged, and the quantity of silicon and lime are increased. This operation is based upon the following reactions:



The ferrovanadium produced in this manner contains from 4 to 8 per cent. silicon, 30 per cent. vanadium, 0.5 per cent. carbon, 0.05 per cent.

TABLE 17.—Refining Ferrovanadium to Remove Silicon

	6	7	8	9	10	11	12	13	14	15	Average
Charge:											
Ferrovanadium, lb.	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	
Vanadium oxide, lb.	10.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	7.50	7.50	
Lime, lb.	15.00	7.50	7.50	7.50	7.50	7.50	7.50	7.50	11.50	11.50	
Ferrovanadium:											
Vanadium, %	38.50	39.80	39.00	39.65	39.65	35.10	38.75	36.90	36.30	36.40	37.00
Carbon, %	0.52	0.88	0.83	0.85	0.85	0.88	0.71	0.54	0.73	1.34	0.81
Silicon, %	0.23	0.63	0.89	0.96	0.95	1.01	1.08	0.54	0.59	0.19	0.70
Length run, min.	145.00	115.00	150.00	120.00	104.00	100.00	100.00	150.00	143.0	151.00	
Weight metal, lb.	34.00	49.00	54.00	50.50	47.00	37.50	37.50	41.50	41.50	41.00	
Power consumption, kw.-hr. per lb. ferrovanadium	2.40	1.50	1.60	1.30	1.30	1.50	1.50	2.30	2.00	2.00	1.70
Percentage vanadium charged as ferrovanadium recovered as ferrovanadium	73.10	109.00	117.60	111.80	104.00	73.60	81.10	84.50	84.10	82.50	92.10

sulphur, 0.05 per cent. phosphorus. A product containing 2 to 4 per cent. silicon can be obtained in a single operation by reducing the amount of

silicon charged, and allowing a greater loss of vanadium in the slags. The slags from normal operation contain less than 1 per cent. vanadium.

Table 16 shows an average recovery of 75.2 per cent. of the vanadium, with a power consumption of 2.1 kw.-hr. per pound of ferrovanadium. Smelting of iron vanadate shows similar results, except that there is a considerably greater consumption of silicon metal, owing to the necessary reduction of iron oxide.

Refining Ferrovanadium

To obtain a ferrovanadium containing less than 1 per cent. silicon, the 4 to 8-per cent. product from the smelting furnace is refined in the electric furnace with a slag of vanadium oxide, lime, and fluorspar, giving a product containing 35 per cent. vanadium, 0.9 per cent. silicon, 0.5 per cent. carbon, 0.05 per cent. sulphur and 0.05 per cent. phosphorus. In the refining process, the ferrovanadium is simply mixed with the slag-forming materials in proper proportions, melted in the furnace, and tapped. The removal of silicon in this manner is a very simple matter, and much less difficult than refining to remove carbon. The silicon in the ferrovanadium reduces the vanadium from the oxide, and passes off as calcium silicate in the presence of lime. The usual grade of vanadium oxide contains over 80 per cent. V_2O_5 . Iron vanadate contains from 25 to 40 per cent. V_2O_5 . Slag produced by refining contains about 5 per cent. V_2O_5 , and is run back through the refining furnace so that there is no loss of vanadium by this method. Also, there is no danger of reducing the high silica in this slag as it cannot be reduced when silicon is the only reducing agent present.

Results of refining high-silicon ferrovanadium are indicated in Table 17. The ferrovanadium to be refined contained 35.8 per cent. vanadium and 4.95 per cent. silicon; the vanadium oxide contained 75.0 per cent. V_2O_5 , and the lime contained 61.45 per cent. CaO. The carbon in the ferrovanadium product was introduced by the electrodes during both smelting and refining, and some of it came from the silicon metal used in smelting, which contained 90 per cent. silicon, and 0.52 per cent. carbon.

The power consumption was 1.7 kw.-hr. per pound of ferrovanadium produced, which, added to 2.1 kw.-hr. for smelting, gives a total of 3.8 kw.-hr. per pound of refined ferrovanadium. The increase in grade of the ferrovanadium from 35.8 to 37.0 per cent. is due to the replacement of silicon by vanadium during refining. Typical slags from the refining of ferrovanadium to remove silicon are as follows:

	1	2
V_2O_5	1.44%	5.28%
SiO_2	28.03%	31.37%
FeO.....	2.52%	2.19%
CaO.....	53.00%	40.90%
MgO.....		12.7%

The difficulties encountered in the removal of carbon from ferrovanadium are illustrated in Table 18. The carbon of the ferrovanadium could be reduced from 1.5 per cent. to less than 1 per cent., but a considerable quantity of the vanadium originally present in the alloy oxidized and went into the slag. Also, it was difficult to get clean taps, as the metal did not separate readily from the slag.

TABLE 18.—*Refining Ferrovanadium to Remove Carbon*

	16	17	18	19	22	23	24	25
Charge:								
Ferrovanadium, lb.....	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
Lime, lb.....					3.00	3.00	3.00	3.00
Iron scale, lb.....	1.00	2.00	2.00	2.00	1.50	1.50	1.00	1.00
Vanadium oxide, lb.....	0.50	1.00	1.00	1.00	1.50	1.50	1.00	1.00
Fluorspar, lb.....	0.40	0.75	0.75	0.75	0.75	0.75	0.75	0.75
Silica, lb.....					0.75	0.75	0.75	1.25
Per cent. carbon in ferrovanadium refined.....	1.45	1.45	1.45	1.45	1.45	1.34	1.34	1.15
Ferrovanadium produced:								
Carbon, %.....	1.09	1.02	1.03	0.97	1.04	0.79	0.83	0.80
Vanadium, %.....		27.15				27.15	24.20	27.15
Silicon, %.....		0.49				0.24	0.36	0.38
Slag:								
SiO ₂ , %.....						9.16	11.82	27.36
V ₂ O ₅ , %.....						22.77	28.29	6.00
FeO, %.....						9.79	8.47	9.79
CaO, %.....						17.48	12.85	9.53
MgO, %.....						16.24	12.80	16.60
Al ₂ O ₃ , %.....						2.68	4.34	3.38
Length of run, hr.....	1.25	3.00	2.50	2.00	2.50	2.25	2.00	2.00
Weight metal, lb.....	15.00	16.00	21.00	18.00	19.00	21.00		15.00

FERRO-URANIUM

Ore Treatment

All ferro-uranium manufactured in this country is derived from the carnotite ore of Colorado. To put the uranium in a suitable form for the production of ferro-uranium, the ore is first subjected to a wet treatment which has as its main object the extraction of radium, with uranium oxide and vanadium oxide or iron vanadate as byproducts.

In the method of extraction used by the National Radium Institute,¹

¹ C. L. Parsons, R. B. Moore, S. C. Lind, O. C. Schaefer: Extraction and Recovery of Radium, Uranium and Vanadium from Carnotite. U. S. Bureau of Mines, *Bulletin* No. 104 (1915).

a high recovery of radium is the object rather than of uranium and vanadium. The ore is ground to 20 mesh, and is leached with strong hot nitric acid in earthenware pots, the acid being kept near the boiling point with live steam. The charge is stirred with wooden paddles, for about 15 min., and then dumped on an earthenware filter, where it is washed with hot water. The whole operation of leaching, filtering, and washing takes about 7 hr.; a new device for filtering has been installed recently, which reduces the time considerably. The residue goes to the dump, and the solution to wooden tanks, where it is diluted with water. The solution is stirred, and sodium hydroxide runs in slowly to reach as nearly as possible the neutral point without forming a permanent precipitate. Barium chloride and sulphuric acid are stirred in for 1 hr., when the whole solution, containing the barium sulphate precipitate, is elevated to a conical settling tank, where it settles for 4 days.

The solution is decanted into a tank containing boiling sodium carbonate, where the iron, calcium, and most of the aluminum, are precipitated, while the uranium and vanadium go into solution as the double carbonate of uranium and sodium, and sodium vanadate. The solution is boiled for 3 hr. after the acid solution is run in.

The radium-barium sulphates and the associated liquor from the conical tank are run onto an earthenware suction filter, where they are filtered, washed, and finally treated with dilute solution of sodium hydroxide to remove the last traces of free acid. The filtrate is run into the carbonate tank, and the sulphates are dried.

The carbonate solution, carrying the uranium and vanadium, is nearly neutralized with nitric acid, the solution being constantly stirred with compressed air. Then sodium hydroxide is added to the boiling solution until precipitation of sodium uranate is complete. The hot solution from the sodium uranate is completely neutralized with nitric acid, air being blown into the liquid in order to eliminate the carbon dioxide. Ferrous sulphate is then added, the liquid being continually agitated, and the iron vanadate precipitate is filtered and washed. The filtrate from the iron vanadate is almost wholly a solution of sodium nitrate, the main impurity being sodium sulphate. The solution is evaporated in iron tanks, and the crystals are used to make fresh nitric acid for use in the plant. The recovery of radium averages 90 per cent. or better; of uranium, about 85 per cent.; and of vanadium, 30 per cent.

Sodium uranate is converted to uranium oxide by fusion with an alkali chloride, such as sodium chloride, and a carbonaceous material which acts as a reducing agent. This is followed by cooling, dissolving the soluble matter, and washing the residue successively with an alkali solution, water, and acid. This residue is high-grade black oxide of uranium, UO_2 , which is the concentrated material used in the electric-furnace manufacture of ferro-uranium.

Experimental Development of Ferro-uranium

Ferro-uranium was developed not because of any particular need for uranium in steel manufacture, but because of the large quantity of sodium uranate, $\text{Na}_2\text{U}_2\text{O}_7$, that was accumulating as a byproduct of radium production. As the reduction temperature of uranium oxide by carbon is 1490°C ., the electric furnace is the only available means for performing the operation in quantity. The furnace used in the experiments outlined in this paper was a small tilting furnace of the Siemens type, with a steel bottom contact, a rammed magnesite bottom, and a graphite electrode of 4-in. diameter. The power input was 30 to 40 kw. Considerable reactance was connected in the circuit, giving a furnace voltage of 30 to 60 volts.

Preliminary experiments were directed to the production of a 15-per cent. alloy, as several steel manufacturers preferred to try this grade first. Sodium uranate was charged, with petroleum coke as a reducing agent. This 15-per cent. ferro-uranium contained 3 per cent. carbon, and it seemed impossible to reduce the percentage of carbon.

At the start, uranium exhibited one of its fundamental characteristics, its strong affinity for carbon and its tendency to form carbides. Also, in this early work it was found that no fluxing material except fluorspar could be used with sodium uranate; if either lime or silica was added, the uranium remained in the slag with practically no reduction. Here was exhibited its second characteristic, its strong affinity for oxygen, the effect of which is shown in all later work. Because of its high atomic weight, uranium does not hold a large quantity of oxygen in combination, but holds very closely the small quantity which is in combination.

Control of Carbon

Four series of experiments were made with the object of producing low-carbon ferro-uranium containing 15 to 20 per cent. uranium:

- (1) By variation of carbon in the charge.
- (2) By removal of carbon from high-carbon alloy, with iron oxide.
- (3) By removal of carbon from high-carbon alloy, with uranium oxide.
- (4) By use of silicon as a reducing agent.

1. The effect of attempting to control carbon in ferro-uranium by the quantity of carbon charged is shown in Table 19. Except in experiments 3 and 4, the heats were made by melting steel turnings, and then charging a mixture of sodium uranate, coke, and fluorspar. In experiments 3 and 4, the steel turnings were mixed with the rest of the charge.

The sodium uranate used in the experiments recorded in Tables 19 and 20 contained 70 per cent. U_3O_8 , or 59 per cent. uranium. The analysis of the steel turnings was: carbon, 0.31; silicon, 0.098; sulphur,

0.14; phosphorus, 0.107 per cent. The charcoal contained 64.73 per cent. and the coke 83.26 per cent. fixed carbon.

These experiments indicate clearly that a low-carbon ferro-uranium

TABLE 19.—Control of Carbon in Ferro-uranium by Variation of Reduction Carbon

	1	2	3	4	5	6	7	8	9	10
Charge:										
Steel turnings, lb.....	20.00	20.00	20.00	20.00	20.00	20.00	20.00	10.00	10.00	10.00
Sodium uranate, lb.....	22.00	22.00	22.00	22.00	22.00	22.00	15.00	10.00	10.00	10.00
Charcoal, lb.....	44.50	4.50	6.50	6.50	4.50					
Coke, lb.....		6.00			1.00	5.00	10.00	5.00	4.00	3.00
Fluorspar, lb.....	4.00	2.00			3.00	4.00	2.00	3.00	2.00	2.00
Ferro-uranium:										
Uranium, %.....	nil	2.84	nil	2.93	nil	nil	7.72	18.3	20.5	19.5
Carbon, %.....	0.43	3.22	1.94	2.41	1.52	0.84	4.11	3.87	3.49	4.07
Silicon, %.....	1.39	3.01	1.42	0.08	1.13	0.19	1.52	3.03	2.53	2.19
Sulphur, %.....	0.227	nil	0.041	0.05	nil	0.073	nil	nil	nil	nil
Phosphorus, %.....	0.19	0.109	0.177	0.081	0.143	0.143	0.057	0.056	0.11	0.106
Iron, %.....						99.0				
Slag:										
Uranium, %.....	4.44	2.52	37.7		39.3					
Iron, %.....	6.15	5.49	6.51		11.35					
Length of run, min.....	222.0	240.0	185.0	95.0	145.0	170.0	125.0	160.0	78.0	80.0
Weight ferro-uranium, lb...	17.0	20.0	10.0	8.2	19.0	16.6	16.0	7.0	13.5	13.0
Weight slag, lb.....	15.0	1.5	12.0	11.0	22.5					
Recovery of uranium, %.....		4.2		4.3			14.1	21.7	46.9	42.7
Kw-hr. per lb. ferro-uranium tapped.....	5.3		8.3	7.5	3.2	5.6	4.8	12.1	3.4	3.4
Carbon charged per lb. of uranium, lb.....	0.22	0.57	0.33	0.33	0.28	0.31	0.41	0.70	0.56	0.42

cannot be made by regulating the amount of carbon charged, as is the case with some other ferro-alloys. Because of its high reduction temperature, the reduction of uranium from sodium uranate requires carbon

about 400 per cent. in excess of the amount theoretically necessary. Theoretically, reduction takes place according to the reaction:



Until, for every pound of uranium, there is 0.4 lb. of carbon in the charge, very little reduction of uranium occurs. From 0.4 lb. carbon to 0.7 lb. carbon per pound of uranium, the percentage of uranium in the alloy varies little, although the recovery at this point is only about 45 per cent. Allowing for 15 per cent. mechanical loss, giving a theoretical recovery of 60 per cent. of the uranium, it appears that recovery of uranium, with over 0.7 lb. carbon per pound of uranium in the charge, would not increase, other conditions being the same. Hence it seems that increased recovery of uranium depends on a more efficient reduction furnace, and a higher temperature. It is possible, also, that better results may be obtained with another slag than fluorspar, or without any slag at all. Silica would suggest itself, as it might form sodium silicate.

At 0.4 lb. carbon per pound of uranium in the charge, the percentage of carbon in the alloy begins to vary a little, remaining between 3.5 and 4.0 per cent., up to 0.7 lb. carbon per pound of uranium. The critical point in this case is also 0.4 lb. carbon per pound of uranium, which was the point at which the percentage of uranium in the alloy became fixed within certain limits.

Curves show that until there is 3.5 per cent. carbon in the ferro-uranium, there will be little absorption of uranium; above 3.5 per cent. carbon, the uranium content varies little. The results on this point are not complete, but in general it appears that the carbon has to be over 2.5 per cent. before the alloy will contain any uranium, and at 3.5 per cent. to hold any large amount of uranium.

2. Table 20 shows the results of attempting to decarburize ferro-uranium with iron scale and silica, and with iron scale alone. The ferro-uranium was first melted before charging the iron scale and silica. The scale contained 71.55 per cent. iron.

The results of Table 20 show conclusively that ferro-uranium cannot be decarburized by the use of iron scale, because the uranium has so great a tendency to form iron uranate that it all passes into a slag and out of the ferro-uranium. Some of the carbon, however, is removed by this method.

3. Two experiments were made on the decarburization of ferro-uranium by the use of uranium oxide. A charge of 15 lb. of ferro-uranium, containing 14.25 per cent. uranium and 3.17 per cent. carbon, was melted with 7 lb. of uranium oxide containing 83.5 per cent. U_2O_5 . The metal from the furnace contained no uranium and 2.95 per cent. carbon. In the second experiment, a carbon-lined furnace was used, to eliminate any oxidizing effect of the magnesite. A charge of 15 lb. of

ferro-uranium, containing 13.65 per cent. uranium and 3.17 per cent. carbon, was charged with 6 lb. of uranium oxide containing 83.5 per cent. U_3O_8 . The carbon-lined furnace would naturally tend to increase the carbon in the alloy, but uranium should remain in the metal under these conditions, if it would remain there under an oxide slag in any furnace. After keeping the metal in the furnace for nearly 2 hr., the tapped metal contained no uranium, and 3.98 per cent. carbon.

TABLE 20.—Decarburizing Ferro-uranium With Iron Scale

	11	12	13	14	15
Charge:					
Ferro-uranium, lb.....	16.0	17.50	12.2	14.0	16.0
Iron scale, lb.....	8.5	7.00	6.2	2.5	3.0
Silica sand, lb.....	4.5	4.75	3.3		
Composition of ferro-uranium charged:					
Uranium, %.....	7.72	6.81	8.53	8.85	5.32
Carbon, %.....	4.11	2.9		2.66	4.09
Silicon, %.....	1.52	1.62		1.93	1.60
Sulphur, %.....	nil	nil		nil	nil
Phosphorus, %.....	0.057	0.181		0.067	0.061
Composition of alloy produced:					
Uranium, %.....	nil	nil	nil	nil	nil
Carbon, %.....	3.31	2.52	2.79	3.51	1.66
Silicon, %.....	1.74	1.75	nil	0.68	0.89
Sulphur, %.....	nil	nil	nil	nil	nil
Phosphorus, %.....	nil	nil	nil	0.079	0.069
Composition of slag:					
Uranium, %.....	13.37	10.00	10.67		
Length of run, min.....	115.00	180.00	90.00	85.00	80.00
Weight of alloy, lb.....	17.00	18.50	13.50	8.00	14.00
Recovery of uranium.....	nil	nil	nil	nil	nil
Kw.-hr. per lb. alloy tapped.....	3.9	4.4	3.2	5.2	2.8

These two experiments showed conclusively that ferro-uranium cannot be decarburized by the use of uranium oxide, because the uranium is entirely removed from the alloy.

4.—Table 21 covers experiments on the production of ferro-uranium with silicon as a reducing agent, according to the reaction:



The raw materials were of the same composition as those used in the experiments of Table 20, and the silicon metal contained 90 per cent. silicon.

Ferro-uranium cannot be made by the use of silicon as a reducing agent, with either an efficient recovery of uranium or a low-silicon content of the alloy.

TABLE 21.—*Silicon Reduction of Ferro-uranium*

	16	17	18	19	20
Composition of charge:					
Steel turnings, lb.....	10.0	10.0	10.0	10.0	10.0
Sodium uranate, lb.....	10.0	10.0	10.0	10.0	10.0
Silicon, lb.....	6.0	4.5	3.5	3.5	2.5
Fluorspar, lb.....	2.0	2.0	2.0	2.0	2.0
Composition of metal:					
Uranium, %.....	2.95	4.01	1.6	12.3	9.47
Silicon, %.....	23.62	17.58	14.44	14.83	14.81
Carbon, %.....	0.25	0.31	1.22	1.64	0.70
Length of run, min.....	135.00	120.00	100.00	120.00	105.00
Weight ferro-uranium, lb.....	13.20	13.00	11.00	9.0	4.5
Recovery of uranium, %.....	6.40	8.80	2.80	18.70	7.20
Kw.-hr. per lb. ferro-uranium tapped	4.60	5.00	4.80	8.30	13.30

Use of Uranium Oxide Instead of Sodium Uranate

Two experiments were made to determine the difference as to recovery of uranium and carbon content of ferro-uranium made from sodium uranate and from uranium oxide; the results are shown in Table 22. The sodium uranate contained 78 per cent. U_3O_8 or 65 per cent. uranium; the uranium oxide contained 82 per cent. U_3O_8 or 68.8 per cent. uranium. The coke analyzed 70 per cent. fixed carbon; the steel turnings, 0.31 per cent. carbon; and the steel stay-bolts, 0.11 per cent. carbon. Except for about two-thirds of the fluorspar, all of the charge was added as soon as the steel was melted.

TABLE 22.—*Uranium Recovery and Carbon Content with Sodium Uranate and with Uranium Oxide*

Composition of charge:	21.—From Sodium Uranate	22.—From Uranium Oxide
Steel turnings, lb.....	10.00	10.00
Steel stay-bolts, lb.....		10.00
Sodium uranate, lb.....	8.75	
Uranium oxide, lb.....		7.75
Coke, lb.....	5.0	6.00
Fluorspar, lb.....	7.0	8.0
Composition of metal:		
Uranium, %.....	25.10	29.20
Carbon, %.....	2.89	5.12(a)
Silicon, %.....	4.88	2.68
Length of run, min.....	120.00	105.00
Weight ferro-uranium, lb.....	14.20	14.25
Recovery of uranium, %.....	63.80	76.20
Kw.-hr., per lb. ferro-uranium tapped.....	4.8	4.40

(a) Graphitic carbon, 1.53 per cent.

The uranium recovery, when using uranium oxide, is 12.4 per cent. higher than from sodium uranate. The ferro-uranium from heat No. 21 is low in carbon because of the high silicon, which throws carbon out of the alloy. No. 22 ferro-uranium is high in carbon, showing 1.53 per cent. graphitic carbon, because more carbon was charged than was needed for reduction. The carbon charged was figured in the same ratio to uranium as when sodium uranate was used, but uranium oxide here showed that it required less carbon per pound of uranium to give a good reduction.

From a commercial standpoint, all of these experiments were a failure. A low-carbon alloy could not be made by variation of the carbon in the charge, because there was such a low recovery of uranium, both when the amount of carbon charged was about the theoretical amount required, and when the carbon in the ferro-uranium was low. The carbon could not be removed from a high-carbon alloy with either iron oxide or uranium oxide, because the uranium in the alloy oxidized out of the metal and went into the slag, leaving pig iron in the furnace. Silicon reduction gave such a low recovery of uranium that its results were valueless. These negative results were caused by the two predominant characteristics of uranium which have been mentioned. Both analytical and microscopic examinations indicated that when there was enough carbon present to form the double carbide of iron and uranium, $\text{Fe}_3\text{C} \cdot \text{U}_2\text{C}_3$, the ferro-uranium held the uranium, and only then. The net result of this work was the production of a ferro-uranium containing 15 to 30 per cent. uranium and 2.5 to 4 per cent. carbon.

Tests on Production of Uranium Metal

As it did not seem possible to produce a ferro-uranium containing 30 per cent. uranium with less than 3 per cent. carbon, experiments were made on production of as high-grade a uranium alloy as possible, with view to decreasing the ratio of carbon to uranium, while holding the carbon to less than 5 per cent., and uranium over 85 per cent.

Experiments were also made on the reduction of uranium oxide with sodium, aluminum, and silicon as reducing agents.

Six ounces of metallic sodium was placed with 1 lb. of uranium oxide, containing 91 per cent. U_3O_8 , in a graphite crucible heated by gas. After 18 hr., the crucible was removed; there was no reduction of uranium and the crucible had been destroyed. The experiment was repeated for 5 hr. with negative results.

An attempt was made to reduce 1 lb. of uranium oxide with 2 oz. of coke in a gas-fired crucible. Heating was continued for 18 hr. The crucible was destroyed and there was no reduction.

A mixture of aluminum, silicon, and carbon was tried as a reducing

agent, using Siemens furnace with carbon bottom and magnesite sides. A charge of 15 lb. of fluorspar was melted, and then a mixture of 20 lb. uranium oxide, 10 lb. petroleum coke, 1 lb. aluminum shot, and 0.75 lb. silicon metal was added, followed, toward the end, by 15 lb. of fluorspar. The length of the run was 3 hr. The furnace was allowed to cool and a small button of metal was removed, which contained: uranium, 11.85; vanadium, 8.66; iron, 52.16; carbon, 1.12; silicon, 13.25, and aluminum, 12.96 per cent. During the experiment there appeared to be a reduction, but it evidently was aluminum burning.

TABLE 23.—*Production of Uranium Metal*

	23	24	25	26
Charge:				
Uranium oxide, lb.....	15.00	20.00	20.00	20.00
Petroleum coke, lb.	5.75	3.00	2.00	2.00
Metal:				
Uranium, %.....	85.50	88.10	93.00	88.00
Carbon, %.....	9.31	7.49	4.39	3.67
Silicon, %.....	0.29	1.48	1.43	2.47
Iron, %.....	0.82	2.43	1.35	1.03
Vanadium, %.....	3.64	1.82	1.21	1.14
Phosphorus, %.....	.....	.....	0.051	.....
Sulphur, %.....	.....	.....	0.13	.....
Residue:				
Uranium, %.....	57.76	19.76		
Carbon, %.....	12.32	2.65		
Silica, %.....	.....	6.62		
Iron, %.....	.....	3.42		
CaO, %.....	.....	12.67		
MgO, %.....	.....	6.57		
Length of run, min.....	105.00	280.00	133.00	170.00
Weight metal, lb.....	6.94	13.20	9.75	9.31
Recovery of uranium, %.....	49.30	76.40	56.30	50.80
Uranium content, (by diff.) %.....	85.94	86.78	91.44	91.69
Kw.-hr. per lb. metal tapped.....	12.90	11.10	7.60	9.60
Carbon charged per lb. uranium, lb.....	0.42	0.16	0.10	0.10

In another experiment in the same furnace, 15 lb. fluorspar was melted, and the following charge added slowly: 20 lb. uranium oxide, 2.8 lb. aluminum shot. The length of the run was $2\frac{1}{2}$ hr. On cooling the furnace, 1 lb. of metal was obtained which contained no uranium. There was a violent reaction when charging, probably due to burning of aluminum.

Subsequent to these preliminary experiments, ferro-uranium was made by William Y. Bleakley, using aluminum as a reducing agent.

He states that the uranium content is easily controlled, and that the carbon can be held under 1 per cent. and the aluminum from 3 to 5 per cent.

Table 23 contains the results of experiments on the production of uranium metal, using carbon as a reducing agent, in Siemens furnace with magnesite walls and carbon bottom. The metal was allowed to cool in the furnace. In experiments No. 23 and 24, the uranium oxide contained 91 per cent. U_3O_8 , but in the other runs it contained 94.7 per cent. U_3O_8 . The analysis of the petroleum coke was: fixed carbon, 85; ash, 3.81; and volatile matter, 11.89 per cent.

The results in Table 23 indicate that a uranium metal can be made containing over 90 per cent. uranium and from 3.5 to 4 per cent. carbon. The production of this low-carbon metal, with the minimum amount of carbon charged, depends entirely on manipulation of the electric furnace, a very high temperature being necessary.

The product in each case, except No. 23, is uranium metal or an alloy of uranium carbide and uranium metal. In No. 23, the product, as shown under the microscope, is almost entirely uranium carbide. No. 24 is an alloy of uranium carbide and uranium, with a considerable proportion of carbide. Products No. 25 and 26 are almost all uranium, with a very small amount of uranium carbide. The silicon and iron can be kept at about 1.5 per cent. each, and the vanadium at 1.25 per cent., with the oxide used.

The uranium recovery in a single operation will be from 50 to 60 per cent. The material left in the furnace is a mixture of pure oxide and carbon, which can be charged again as soon as its carbon content is determined. In this way, the ultimate recovery of uranium is high, well over 85 per cent. The power consumption is high, because pure uranium oxide is being reduced. It averages about 8 kw.-hr. per pound of metal.

Further experiments were made, Table 24, in an attempt to produce a lower-carbon uranium metal. The furnace was lined both on sides and bottom with magnesite, the bottom contact being a $\frac{1}{2}$ -in. carbon rod. In each run the charge was added slowly, at the rate of $\frac{3}{4}$ lb. of charge every 5 min.; the metal was left in the furnace until cool. The petroleum coke contained 85 per cent. fixed carbon.

The experiments of Table 24 do not permit different conclusions from those previously made regarding the production of uranium metal. The last series of experiments indicates that when an attempt is made to produce an alloy containing under 1 per cent. carbon, the greater part of the product is UO_2 mixed with uranium carbide and a little metallic uranium. The products obtained in experiments Nos. 27 to 31, inclusive, were of this character, judging from the uranium content and the nonmetallic appearance of the material.

When the carbon was from 1 to 2 per cent., the product was a mixture of uranium metal, uranium carbide, and uranium oxide. Of the total uranium, the amount present as oxide varies from 12 to 40 per cent.

TABLE 24.—*Production of Uranium Metal*

	27	28	29	30	31	32	33	34	35	36	37
Composition of charge:											
Uranium oxide (80.5% U) lb.	20.0	20.0	10.4								
Uranium oxide (69.5% U) lb.			20.0								
Uranium oxide (72.5% U) lb.				35.0		18.75					
Uranium oxide (73.0% U) lb.							20.0	20.0	20.0	45.0	47.0
Uranium oxide (87.7% U) lb.					24.5						
Uranium slag (57.7% U) lb.							20.75				
Uranium oxide (84.8% U) lb.				10.3							
Petroleum coke.....	1.87	1.81	2.81	4.5	3.0	2.38	5.5	3.5	3.5	7.87	7.87
Composition of product:											
Uranium, %.....	84.8	83.7	81.5	85.5	87.5	88.8	85.28	86.73	79.0	83.4	85.8
Carbon, %.....	0.63	0.45	tr.	0.49	0.9	1.47	2.06	3.95	4.70	1.4	4.52
Silicon, %.....	0.73	1.08	0.29	0.09	1.27	0.23	0.96	0.42	0.94	0.36	0.36
Iron, %.....	0.47	0.16	tr.	tr.	1.15	tr.	2.83	1.25	4.19	0.73	1.03
Vanadium, %.....	0.97	1.15	0.33	1.95	1.85	2.16	2.96	3.91	3.22	3.03	2.82
Length of run, min.....	150.0	165.0	155.0	360.0	180.0	120.0	300.0	195.0	195.0		
Weight metal, lb.....	29.5	7.75	17.0	17.25	8.5	9.83	19.0	11.3	18.0	17.25	13.87
Recovery of uranium, %.....	47.4	38.1	57.9	43.5	36.2	63.7	50.5	67.1	97.3		
Oxygen consumed on ignition.....						11.49	13.42	17.56	18.03	10.62	17.52
Uranium present as metal, %.....						37.6	58.5	39.8	21.4	49.8	33.9
Uranium present as carbide, %.....						21.8	29.5	60.2	78.6	22.1	66.1
Uranium present as oxide, %.....						40.6	12.0	nil	nil	28.1	nil
Kw.-hr. per lb. of product.....	9.0	10.6	6.3	10.0	12.7	6.2	7.6	18.8	11.8	.....	.....
Carbon charged per lb. uranium, lb.....	0.1	0.09	0.104	0.15	0.19	0.15	0.17	0.2	0.2	0.2	0.19

The product was high in uranium but low in impurities, also showing that reduction was not complete.

When the carbon in the product is from 3.5 to 5 per cent., all of the uranium is present as carbide or metal. Of the total uranium present,

25 to 50 per cent. is metal and the rest carbide. These conclusions were confirmed by microscopic examination, in addition to determination of oxide by analysis.

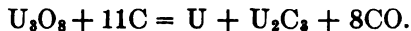
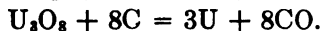
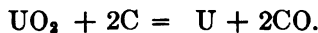
An interesting feature developed in these experiments was the ease with which metallic uranium oxidizes. In working with a charge which produced uranium, or metal and carbide, if the button of sponge metal was removed from the furnace while still red hot, and exposed to the air, it immediately oxidized to black uranium oxide, a 25-lb. button being converted completely to oxide in less than 5 minutes.

Manufacture of Uranium Metal

The materials used in the manufacture of uranium metal are uranium oxide and petroleum coke. Both of these materials should be low in impurities, especially in iron and silica. The most suitable furnace for the production of uranium metal is a stationary Siemens electric furnace, having the crucible bottom as one electrode and a single suspended electrode. The lining is ground, dead-burned magnesite, rammed into place with pitch as a binder, and the bottom electrical connection is made by a small graphite rod buried in the magnesite. Fireclay tiles of hexagon cross-section also may be used for a furnace.

Uranium oxide and petroleum coke are mixed in proper proportions and charged slowly into the furnace. To secure the proper temperature, the furnace must arc all the time. Regular charging is necessary. The uranium metal is allowed to form a sponge on the bottom of the furnace, which gradually builds up. Directly beneath the electrode, this sponge is pasty, but not fluid. The charge forms its own furnace lining. When a run is finished, the button of uranium metal is removed from the furnace. The unreduced residue is re-treated with another charge.

The reaction involved is a simple carbon reduction, and the product consists of a mixture of metallic uranium and uranium carbide.



A typical charge for the production of uranium metal would be: uranium oxide, 20 lb.; petroleum coke, 2 lb., the oxide containing 94.7 per cent. U_3O_8 , and the petroleum coke, 85 per cent. fixed carbon.

Making a recovery of 56 per cent. of the uranium, 100 lb. of this charge will produce 44 lb. of uranium metal. By resmelting the residue, practically all of the uranium can be recovered except the small amount lost mechanically.

The uranium metal made from this charge contained: uranium, 93.0; carbon, 4.39; silicon, 1.43; iron, 1.35; vanadium, 1.31; phosphorus, 0.051; sulphur, 0.13 per cent.

Addition of Uranium Metal to Steel

Steel manufacturers who had been trying ferro-uranium for making high-speed steel reported that they could not make uranium stay in the steel, getting a recovery from zero to 50 per cent., when using the 15 to 30-per cent. grade of ferro-uranium. Uranium metal was submitted with the expectation that a 75 per cent. recovery would be made, on addition to steel, but they reported the same results as before.

A series of tests was made on the production of a uranium steel by the addition of uranium metal, Table 26. The steel was made, in each case, in a tilting Siemens furnace-lined with magnesite. Stay-bolts were first melted with a slag of lime, iron scale, and fluorspar; the slag was skimmed, and a second charge of lime and fluorspar was added. The first slag was

TABLE 25.—*Analyses of Materials Used in Making Uranium Steel from Uranium Metal*

Stay-bolts		Lime		Iron Scale	
C.....	0.11 %	CaO.....	61.45%	Fe.....	71.55%
Mn.....	nil %	MgO.....	11.34%	Petroleum Coke	
Si.....	0.14 %	SiO ₂	2.48%	Fixed C.....	84.8 %
P.....	0.148%	Vol.....	24.42%	Volatile.....	11.39%
S.....	0.014%			Ash.....	3.81%
Fluorspar No. 1		Fluorspar No. 2		Uranium Metal	
CaF ₂	89.43%	CaF ₂	63.04%	U.....	80.28%
SiO ₂	0.21%	SiO ₂	5.80%	C.....	4.43%
Al ₂ O ₃	4.28%			Si.....	0.60%
Fe ₂ O ₃	nil			Fe.....	2.39%
CaCO ₃	1.21%			V.....	3.24%
		Ferromanganese.. 80% Mn			
		Ferrosilicon..... 50% Si			
		Silica, high-grade sand			
		Aluminum, shot			

for keeping down the carbon and phosphorus, and the second to take care of the sulphur. When the second slag was melted, petroleum coke was added. The slag then turned white; if it became black again, more coke was added. Before pouring, ferromanganese and ferrosilicon were charged into the furnace, and shortly afterward the uranium was added, if the test called for its addition in the furnace. In some runs, only the second type of slag was used, and in some runs this slag contained silica as well as lime and fluorspar. Aluminum was sometimes added, in the ladle. To test the effect of adding uranium metal with a slag of fluorspar instead of lime and fluorspar, in some experiments the second slag was skimmed and was followed by a slag of fluorspar. If necessary, coke

TABLE 26.—*Uranium Steel by Addition of Uranium Metal*

	38	39	42	43	44	45	49	50	51	52	53	55	56	57	58
Charge:															
1st Slag:	20.0	20.00	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0
Lime, lb.	.....	.....	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Iron scale, lb.	.....	.....	0.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Fluorspar No. 1, lb.	.....	.....	0.25	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Fluorspar No. 2, lb.	.....	.....	.....	0.375	0.375	0.375	0.375	0.375	0.375	0.375	0.375	0.375	0.375	0.375	0.375
2d Slag:															
Lime, lb.	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Silica, lb.	0.375	0.375	0.375	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Fluorspar No. 1, lb.	1.0	1.0	1.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Fluorspar No. 2, lb.	.....	.....	.....	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
3d Slag:															
Fluorspar No. 2, lb.	.....	.....	.....	4.0	4.0	3.0	.....	.....	.....	.....	.....	.....	.....	.....	.....
Petroleum coke, grams	84.0	56.0	84.0	84.0	112.0	112.0	84.0	84.0	84.0	112.0	140.0	112.0	112.0	162.0	162.0
Ferromanganese, grams	168.0	168.0	70.0	25.0	25.0	25.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	40.0	40.0
Ferrosilicon, grams	.....	.....	56.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	10.0	10.0
Aluminum, grams	.....	.....	1.5	1.0	1.0	1.0	.....	.....	.....	.....	.....	.....	.....	.....	.....
Uranium metal, grams	28.0	28.0	28.0	142.0	142.0	115.0	170.0	170.0	170.0	170.0	170.0	170.0	170.0	170.0	170.0
Analysis steel:															
Carbon, %	1.50	1.11	1.86	0.31	0.90	0.47	0.24	0.24	0.12	0.75	0.44	0.29	0.32	1.31	0.50
Manganese, %	0.75	1.84	0.08	0.10	0.03	0.10	0.24	0.17	0.12	0.01	0.25	0.13	0.25	0.46	0.39
Silicon, %	1.18	0.58	0.98	0.06	0.197	0.193	0.047	0.05	0.03	0.28	0.24	0.19	0.14	0.74	0.54
Phosphorus, %	0.134	0.155	0.068	0.062	0.061	0.069	0.07	0.05	0.025	0.19	0.13	0.13	0.11	0.13	0.08
Sulphur, %	0.03	0.016	0.044	0.03	0.038	0.027	0.02	0.03	0.04	0.008	0.016	0.016	0.014	0.005	0.008
Uranium, %	nil	nil	nil	nil	nil	nil	0.18	nil	nil	0.14	0.07	0.04	0.07	0.24	0.27
Uranium added in:															
Slag on steel when adding uranium	2d	2d	2d	3d	3d	3d	none	none	none	2d	2d	2d	2d	none	none
Uranium in furnace, min.	5.0	8.0	6.0	1.0	21.0	15.0	0.0	2.0	0.0	3	1.0	3.0	0.0	0.0	0.0
Recovery of uranium, %	0.0	0.0	0.0	0.0	0.0	0.0	11.6	0.0	0.0	9.0	4.5	2.5	4.5	15.4	17.4

F—Furnace. L—Ladle. In experiments 40, 41, 46, 47, 48, omitted from table for lack of space, the recovery of uranium was 0. In experiment No. 54, omitted, the conditions and results were practically identical with those of No. 53, except that the uranium was in the furnace for 2 min.

was thrown on this slag. A graphite crucible was used as a ladle. The steel was poured into molds of 2- or 3-in. square cross-section, or into pigs.

The composition of the raw materials used are shown in Table 25. The uranium metal and all of the ferro-alloys were crushed to about pea size.

In experiments No. 38 to 42, inclusive, the uranium metal was added to the steel, in the furnace, after addition of ferromanganese and ferro-silicon, and was left there for 5 to 10 min.; no uranium was found in the steel. The lime-fluorspar-silica slag was on the steel while the uranium was in the furnace.

In experiments No. 43 to 49, inclusive, the second slag was skimmed and a slag of fluorspar was placed on the steel. Then the ferromanganese and ferrosilicon were charged, followed by the uranium metal. The steel was then left in the furnace for from 1 to 15 min. before pouring. Even with the fluorspar slag, no uranium was found in the steel; but most of it was in the slag, as shown in the following analyses. The character of the steel to which the uranium was added is shown also, the carbon sample having been taken before addition of uranium metal.

No.	Uranium in Slag, Per Cent.	Carbon in Steel, Per Cent.
43	2.01	0.13
44	1.34	0.16
45	2.01	0.33
46	2.35	0.08
47	3.81	0.09
48	3.65	0.16

The uranium content of the slag indicates that the uranium metal was melting partially, but slagged at once if any slag was present.

As a result of the slag analyses, a test was made in which the uranium was thrown into the molten stream while the steel was being poured from the furnace into the ladle; before pouring, the slag was skimmed from the steel. This run, No. 49, was the first to yield steel containing uranium. In experiments No. 49 to 59, the uranium metal was added either in the ladle, in the furnace after skimming the slag, or in the furnace with the slag, a variable length of time elapsing after the addition of uranium. The best results were obtained in No. 57 and 58, in which the slag was skimmed, the steel poured, and the uranium thrown into the stream of metal as it entered the ladle. In No. 51, the uranium metal was placed in the ladle before pouring, with negative results, the uranium forming a cake which did not melt.

Uranium metal is not a satisfactory agent for the addition of uranium to steel, for two reasons:

(1) It has such a high melting point that if it is added to the steel in the furnace just before pouring, or in the ladle, all of the metal is not melted, and only a comparatively small proportion enters the steel.

(2) When it is left in the steel bath for a period long enough to melt it, it passes into the slag and oxidizes so easily that no uranium is recovered in the steel; it all slags off.

The first conclusion is based on the results obtained in tests No. 49 to 58, inclusive, in each of which a considerable amount of uranium metal was found untouched after pouring, whether it was added in the furnace or in the ladle.

TABLE 27.—*Raw Materials for Making Ferro-uranium*

Steel Turnings		Petroleum Coke No. 1		Fluorspar	
Carbon.....	0.20%	Carbon.....	85.44%	CaF ₂	89.43%
Manganese.....	0.74%	Volatile.....	11.63%	SiO ₂	0.21%
Silicon.....	0.118%	Ash.....	2.93%	CaCO ₃	1.21%
Phosphorus.....	0.092%			Al ₂ O ₃	
Sulphur.....	0.101%			Fe ₂ O ₃	4.28%
Uranium Oxide No. 1		Uranium Oxide No. 2			
Uranium.....	73.7%	U.....	73.33%		
SiO ₂	2.2%	V.....	5.07%		
		SiO ₂	2.39%		
Sodium Uranate					
	1	2	3	4	
U ₃ O ₈	65.40%	81.40%	67.70%	60.70%	
V ₂ O ₅	5.47%	1.20%	3.04%	2.71%	
FeO.....	1.06%	Tr.	Tr.		
SiO ₂	1.06%	2.17%	3.83%	8.87%	
Al ₂ O ₃	4.77%	0.70%	5.50%		
Uranium Slag No. 2		Uranium Slag No. 1		Uranium Slag No. 3	
Uranium.....	57.0%	Uranium.....	44.1%	Uranium.....	41.84%
Fe ₂ O ₃	23.6%	Carbon.....	5.88%	Carbon.....	3.50%
SiO ₂	3.5%	Vanadium.....	1.04%	Iron.....	12.96%
		Iron.....	10.76%	SiO ₂	2.10%
		SiO ₂	3.14%		

The second conclusion is based on all of the experiments up to No. 49, no uranium having been found in the steel when the metal was left in the furnace for any length of time. The character of the slag on the steel at the time the uranium is added apparently has no effect on the recovery of uranium; hence the slag can be selected to produce the best steel.

It is not probable that a recovery of over 25 per cent. of the uranium can be expected by the use of uranium metal, and this will be difficult to attain when it is desired to add uranium in large amounts. To date, the use of uranium metal does not offer much encouragement for a high

recovery of uranium, and only when it is added to the steel in the ladle is there any great degree of success.

Tests on Production of 50-per cent. Ferro-uranium

Because uranium could not be added to steel as uranium metal, experiments were made on the production of a 50-per cent. ferro-uranium. This alloy would have a melting point between 1500 and 1700° C., and its iron should tend to hold the uranium away from the slag when melted.

Three series of experiments were made: Table 28 using uranium oxide, Table 29 using sodium uranate, and Table 30 using the unreduced residues and slags from the runs of Table 24. In Table 27 are given analyses of raw materials charged.

TABLE 28.—*Production of Ferro-uranium from Uranium Oxide and Slag*

	59	60	61	62	63	64
Charge:						
Steel turnings, lb.....	10.0	20.0	15.0	15.0	22.5	22.5
Fluorspar, lb.....	13.0	37.0	25.0	15.0	15.0	20.0
Petroleum coke, lb.....	14.3	25.5	13.0	7.0	7.87	10.5
Uranium slag No. 1, lb.....	52.0	108.0	28.0			
Uranium oxide No. 2, lb.....			26.0			
Uranium oxide No. 3, lb.....				40.0	60.0	60.0
Analysis, ferro-uranium:						
Uranium, %.....	56.50	52.87	60.40	50.40	36.40	37.90
Carbon, %.....	4.47	4.74	4.85	4.95	4.24	4.91
Silicon, %.....	2.54	2.33	1.19	1.16	1.79	2.00
Vanadium, %.....	2.31	2.15	1.69	3.25	4.81	4.29
Iron, %.....	33.80	37.20	29.36	39.33	46.20	50.10
Graphite, %.....	0.40	0.07	nil	nil	nil	nil
Phosphorus, %.....	0.072	0.053	0.099	0.066	0.085	
Sulphur, %.....	nil	nil	nil	nil	nil	
Length run, min.....	405.0	365.0	215.0	170.0	240.0	250.0
Weight ferro-uranium, lb.....	21.0	16.5	40.0	32.0	12.0	11.5
Power consumption per lb., kw.-hr.	8.5	3.4	3.3	2.9	.....	11.6
Uranium recovery, %.....	48.9	55.5	63.1	55.2		

Additional metal cleaned from the furnace was as follows:

Heat No.....	59	60	61	63
Weight metal, lb.....	4.87	24.00	20.00	2.87
Uranium, %.....	54.50	56.81	59.38	45.15
Carbon, %.....	6.44	6.88	5.77	4.39
Silicon, %.....	2.64	2.06	2.04	
Vanadium, %.....	2.21	2.10	1.82	
Iron, %.....	33.20	32.70	30.20	
Graphite, %.....	1.75	1.26	1.38	
Phosphorus, %.....	0.069	0.056	0.052	
Sulphur, %.....	nil	nil	nil	

The general procedure in all of these experiments, except No. 59 and 60, was to mix the iron turnings with the rest of the charge and add it

TABLE 29.—*Production of Ferro-uranium from Sodium Uranate*

	68	69	70	71	72	73	74	75	76	78	79	80	81	82	83
Charge:															
Steel turnings, lb.....	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0
Petroleum coke, lb.....	14.0	14.0	10.5	9.3	14.0	14.0	11.0	11.0	14.0	15.0	15.0	15.0	15.0	15.0	15.0
Fluorspar, lb.....	15.0	.....	.....	10.0	15.0	30.0	40.0	30.0	33.0	36.0	36.0	36.0	36.0	36.0	36.0
Sodium uranate No. 1, lb.....	50.0	40.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Sodium uranate No. 2, lb.....	.....	10.0	50.0	34.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Sodium uranate No. 3, lb.....	.....	.....	.....	.....	50.0	50.0	40.0	40.0	50.0	.....	.....	.....	.....	.....	.....
Sodium uranate No. 4, lb.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	60.0	60.0	60.0	60.0	60.0	60.0
Analysis metal:															
Uranium, %.....	41.6	48.3	51.9	46.7	45.1	49.5	32.2	32.28	5.88	49.9	39.0	41.2	.....	.....	.....
Carbon, %.....	5.22	5.56	5.03	6.06	5.5	5.05	4.63	4.63	2.84	5.5	5.4	4.95	.....	.....	.....
Silicon, %.....	0.60	1.16	0.8	1.18	2.14	1.56	1.62	1.62	4.54	3.97	2.6	3.34	.....	.....	.....
Vanadium, %.....	3.35	2.55	0.86	0.81	1.52	1.74	1.88	1.88	1.21	11.9	6.72	18.1	.....	.....	.....
Aluminum, %.....	0.55	1.08	0.55	0.12	0.06	0.13	.....	.....	.....	.....	.....	.....	.....	.....	.....
Length run, hr.....	4.0	4.0	3.2	2.0	2.3	5.6	3.5	3.5	2.6	4.5	4.5	8.0	4.0	4.0	8.0
Weight ferro-uranium, lb.....	36.0	20.0	9.0	16.0	12.0	45.0	none	19.0	8.0	23.0	.....	26.0	none	none	none
Kw.-hr. per lb. ferro-uranium	3.7	6.9	12.2	4.7	13.5	4.4	.....	8.3	19.0	12.3	.....	.....	.....	.....	.....
Recovery of uranium, %.....	47.3	33.7	13.5	23.2	18.9	77.6	.....	26.5	1.7	37.1	.....	.....	.....	.....	.....

slowly to the furnace at the rate of 2 lb. of charge every 5 min. After the last addition of mixed charge, some fluorspar was charged and the fur-

nace operated 15 min. before pouring. In No. 59 and 60, the steel was melted before addition of the rest of the charge.

From the results of Table 28, it is evident that a ferro-uranium containing 40 to 60 per cent. uranium and under 5 per cent. carbon can be made about as readily as a lower-grade alloy. The silicon can be kept generally under 2, but at times is as high as 3 per cent. When the 50-per cent. alloy contains about 5 per cent. carbon, it contains little or no graphite.

The power consumption varies from 3 to 5 kw.-hr. per pound of alloy. A recovery of 50 to 60 per cent. of the uranium charged can be

TABLE 30.—*Production of Ferro-uranium from Slag*

	84	85	86	87	88	89	90*	91	92
Charge:									
Steel turnings, lb.....	14.0	15.0	15.5	13.5	17.0	12.0	.....	13.0	11.5
Fluorspar, lb.....	.....	15.0	15.0	15.0	20.0	15.0	.....	15.0	15.0
Petroleum coke, lb.....	7.0	7.5	7.5	7.5	10.5	7.5	.....	7.5	7.5
Uranium oxide, No. 2, lb.....	40.0	.....	.....	.....	3.5	.....	.....	.....	.....
Uranium slag, No. 2, lb.....	.....	60.0	60.0	60.0	34.5	.....	.....	.....	.....
Uranium slag, No. 3, lb.....	.....	.....	.....	.....	44.0	63.0	.....	63.0	63.0
Analysis metal:									
Uranium, %.....	33.3	43.6	38.29	40.1	39.35	40.0	44.9	42.8	41.9
Carbon, %.....	4.68	4.87	3.8	4.9	4.24	4.52	5.58	4.97	5.02
Silicon, %.....	2.03	3.10	5.36	3.92	6.42	4.09	2.01	2.40	2.02
Vanadium, %.....	4.49	2.72	2.47	2.34	1.82	2.60	2.6	2.08	2.21
Iron, %.....	55.44	42.0	40.46	42.17	37.1	38.6	37.6	43.4	45.85
Length run, min.....	175	275	280	225	330	220	.....	260	235
Weight ferro-uranium, lb.....	5.12	43.75	35.5	37.5	29.0	24.0	29.0	40.0	27.5
Kw.-hr. per lb.....	.....	3.6	4.8	3.7	4.7*	3.4*	.....	3.7	5.0
Uranium recovery, %.....	.....	72.2	55.3	57.0	48.0*	61.0*	.....	65.3	44.0

* No. 90 was metal removed from the furnace bottom after runs No. 88 and 89 and is distributed evenly between them in figuring power consumption and recovery.

made in a single operation. The low recovery in some of the experiments was due to attempts to keep the carbon lower than usual by charging less coke.

The experiments of Table 29 show an average recovery of 31 per cent. of the uranium charged, and a power consumption of 10.5 kw.-hr. per pound of alloy tapped. The results are very irregular, and the carbon has a tendency to be higher than when the alloy is made by reduction of oxide. With the exception of vanadium, the ferro-uranium produced is no higher in impurities than the alloy made from uranium oxide. In general, the use of sodium uranate rather than oxide results in a much lower average recovery of uranium, and a much higher power consumption.

The production of ferro-uranium from slags and unreduced residues,

Table 30, shows about the same recovery and power consumption as when new uranium oxide is charged. The ferro-uranium produced is of a high grade, and cannot be distinguished from the products of Tables 28 and 29 in appearance or analysis.

Percentage Recovery of Uranium

It is now possible to get an idea of the total uranium recovery possible in making ferro-uranium.

	Actual Recovery in Experiments	Estimated Recovery in Practice
Ferro-uranium from sodium uranate.....	63.8 per cent.	75 per cent.
Ferro-uranium from uranium oxide.....	76.2 per cent.	85 per cent.
Ferro-uranium from sodium uranate with slags smelted once.....	87.6 per cent.	91 per cent.
Ferro-uranium from uranium oxide with slags smelted once.....	91.3 per cent.	96 per cent.

From these results, it appears that by smelting the slag, the ultimate recovery of uranium from uranium oxide is not much better, viewed from a commercial standpoint, than from sodium uranate. The use of the oxide, however, may result in so high a recovery in one operation that resmelting the slags will not be necessary. Also, the use of sodium uranate is certain to result in silicon in the alloy, especially in the ferro-uranium made by smelting slags. Uranium oxide must be used to give an alloy low in silicon, in which the only important impurity is carbon, from 3 to 4 per cent.

TABLE 31.—Analyses of Materials Used in Making Uranium Steel with Ferro-uranium

Stay-bolts		Steel Turnings		Ferro-uranium No. 1	
Carbon.....	0.10 %	Carbon.....	0.3 %	Uranium.....	25.1 %
Manganese.....	0.05 %	Manganese.....	0.74 %	Carbon.....	3.78 %
Silicon.....	0.52 %	Silicon.....	0.118 %	Silicon.....	5.73 %
Phosphorus.....	0.028 %	Phosphorus.....	0.092 %		
Sulphur.....	0.021 %	Sulphur.....	0.101 %		
Very variable.					
Nickel-uranium No. 2		Ferro-uranium No. 3		Ferro-uranium No. 4	
Uranium.....	20.83 %	Uranium.....	25.1 %	Uranium.....	24.85 %
Nickel.....	62.6 %	Carbon.....	2.89 %	Carbon.....	4.14 %
Carbon.....	0.36 %	Silicon.....	4.88 %	Silicon.....	4.83 %
Silicon.....	9.6 %	Phosphorus.....	0.074 %		
Iron.....	1.5 %	Sulphur.....	nil		
Aluminum.....	2.07 %				
Ferro-uranium No. 5		Ferro-uranium No. 6		Ferro-uranium No. 7	
Uranium.....	29.2 %	Uranium.....	19.5 %	Uranium.....	37.55 %
Carbon.....	5.12 %	Carbon.....	3.9 %	Carbon.....	3.54 %
Silicon.....	2.68 %	Silicon.....	2.59 %	Silicon.....	2.32 %
				Vanadium.....	1.18 %

TABLE 32.—*Uranium Steel by Addition of Ferro-uranium*

	95	96	97	98	99	100
Charge:						
Stay-bolts, lb.	20.0	20.0	20.0	20.0	20.0	20.0
Steel turnings, lb.						
1st slag:						
Lime, lb.	1.5	1.5	1.5	1.5	1.5	1.5
Iron scale, lb.	1.0	1.0	1.0	1.0	1.0	1.0
Fluorspar, lb.	0.375	0.375	0.375	0.375	0.375	0.375
2d slag:						
Lime, lb.	2.0	2.0	2.0	2.0	2.0	2.0
Fluorspar, lb.	1.5	1.5	1.5	1.5	1.5	1.5
Petroleum coke, grams.	162.0	112.0	112.0	112.0	112.0	112.0
Ferromanganese, grams.	40.0	40.0	40.0	40.0	40.0	40.0
Ferrosilicon, grams.		10.0	10.0	5.0	5.0	
Ferro-uranium, No. 1, lb.	3.06	4.0	2.38	1.18	1.18	1.62
Nickel-uranium, No. 2, lb.	0.69					
Ferro-uranium, No. 3, lb.						
Ferro-uranium, No. 4, lb.						
Ferro-uranium, No. 5, lb.						
Ferro-uranium, No. 6, lb.						
Ferro-uranium, No. 7, lb.						
Analysis steel:						
Carbon, %	0.77	0.61	0.63	0.49	0.50	0.41
Manganese, %	0.46	0.39	0.42	0.39	0.12	0.28
Silicon, %	1.3	0.68	0.83	0.49	0.49	0.38
Phosphorus, %	0.08	0.06	0.10	0.066	0.058	0.045
Sulphur, %	0.011	0.011	0.011	0.009	0.003	0.006
Uranium, %	2.55	2.18	1.81	1.42	1.69	1.02
Nickel, %	2.07					
Vanadium, %						
Slag on steel when adding ferro-uranium.	none	none	none	none	none	none
Uranium in furnace, min.	0.0	0.0	0.0	0.0	0.0	0.0
Recovery of uranium, %	62.8	48.8	65.3	100.0	118.0	53.1
Desired % uranium in steel.	4.06	4.46	2.77	1.42	1.42	1.92

Addition of Ferro-uranium to Steel in Electric Furnace

Experiments were made on the production of uranium steel by the addition of ferro-uranium to molten steel. The steel was made in a tilting Siemens furnace lined with magnesite, by the same procedure described under the use of uranium metal. The ferro-uranium was added either in the ladle or in the furnace. If in the furnace, the addition followed that of ferromanganese and ferrosilicon. Sometimes the slag was skimmed before adding the ferro-uranium; at other times it was left in. The length of time the ferro-uranium remained in the furnace before pouring the steel was also varied, from immediate pouring to one minute. A third slag of fluorspar was not used in these experiments, the tests on uranium metal having shown that it did not increase the recovery.

Analyses of the steel turnings, stay-bolts and ferro-uranium used in the tests are shown in Table 31; other materials were the same as in the

TABLE 32.—Uranium Steel by Addition of Ferro-uranium—(Continued)

102	104	105	108	107*	110	113	115	116	117	118	120
20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0
1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.5
0.375	0.375	0.375	0.375	0.375	10.375	0.375	0.3	0.375	0.375	0.375	0.375
1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
1.0	1.0	1.0	1.0	0.75	1.0	1.0	1.0	1.0	1.0	1.0	0.75
112.0	112.0	112.0	112.0	112.0	196.0	196.0	196.0	112.0	112.0	112.0	112.0
40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0
3.18	2.38	3.31									
.....	.....	1.44	5.38	0.38							
.....	.....	.....	.....	3.0							
.....	.....	.....	.....	.....	2.75						
.....	.....	.....	.....	.....	.....	3.12	5.18	5.18	6.18		
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	3.18	3.18
0.55	1.13	0.74	0.65	0.67	0.83	0.86	0.83	2.13	1.11	1.23	0.98
0.18	0.35	0.38	0.42	0.33	0.08	0.20	0.56	0.75	0.54	0.17	0.49
0.78	2.20	1.42	1.67	0.85	0.55	0.51	0.99	0.73	0.52	0.81	0.49
0.033	0.055	0.045	0.057	0.016	0.04	0.070	0.098	0.078	0.086	0.086	0.064
0.006	0.007	0.07	0.005	0.009	0.003	0.003	0.004	0.002	0.003	0.003	0.008
2.55	1.19	2.58	2.58	2.17	1.69	1.79	1.66	2.30	0.44	2.26	3.7
2d	2d	2d	0.08	0.22	2d	2d	2d	2d	2d	2d	2d
1.0	1.0	1.0	1.0	0.07	1/4	1/4	1/4	0.0	0.0	0.0	0.0
68.3	42.0	50.2	45.1	63.6	45.6	55.8	39.1	54.2	8.9	41.4	67.9
3.73	2.78	5.14	5.72	3.41	3.7	2.72	4.24	4.24	4.92	5.45	5.45

* 6 oz. nickel shot in charge.

The following numbered tests have been omitted from the table, for want of space: No. 94 and 101, conditions and results similar to those of No. 95 to 100. No. 103, similar to No. 102 and 104. No. 108, similar to No. 107 except in regard to nickel. No. 109 and 111, similar to No. 110. No. 112 and 114, similar to No. 113. No. 119, similar to No. 118 and 120.

tests with uranium metal. In experiments No. 94 to 97, inclusive, the ferro-uranium was broken to pea size; in the remaining tests, it was about $\frac{1}{2}$ -in. size.

On studying the results of these experiments, it may be noticed that in some tests there are several variable factors, so that conclusions as to what caused the results must be made with care. Due to the considerable mechanical loss of steel in pouring such small charges, the efficiency could not be calculated from the analysis of the steel and its weight. The uranium recovery is to a certain extent approximate. It is calculated on the assumption that all of the iron in the ferro-uranium combines with the weight of steel charged into the furnace.

This total weight is used as a basis for figuring the desired percentage

of uranium in the steel, which, compared with that actually secured, gives the uranium recovery. This method of computation is more accurate than one based on the weight of metal poured, in that it shows what may be expected under operating rather than experimental conditions.

The average uranium recovery in all of the 27 runs was 54.7 per cent.; when a steel containing less than 2 per cent. uranium was the object, the recovery was 67.8 per cent. Figures on average recovery under different conditions are given in Table 33.

TABLE 33.—*Average Recovery of Uranium under Different Conditions*

Average of all tests.....	54.7 per cent.
Steel containing less than 2 per cent. uranium.....	67.8 per cent.
Ferro-uranium added after skimming.....	70.7 per cent.
Ferro-uranium added before skimming.....	48.3 per cent.
Poured at once after adding ferro-uranium.....	60.2 per cent.
Poured $\frac{1}{4}$ min. after adding ferro-uranium.....	45.3 per cent.
Poured $\frac{1}{2}$ to 1 min. after adding ferro-uranium.....	56.7 per cent.
Recovery with alloy No. 1 (25.1 % U).....	65.1 per cent.
Recovery with alloy No. 3 (25.1 % U).....	45.1 per cent.
Recovery with alloy No. 4 (24.85% U).....	49.1 per cent.
Recovery with alloy No. 5 (29.2 % U).....	45.7 per cent.
Recovery with alloy No. 6 (19.5 % U).....	44.1 per cent.
Recovery with alloy No. 7 (37.55% U).....	52.1 per cent.

All of the steels were cooled in lime. Some drilled with considerable difficulty, but no relation between ease of drilling and uranium content could be observed, because of cooling from and to different temperatures. All of the uranium steels are brittle when cooled slowly, and some when chilled. The slowly cooled steel has a coarse fracture, and the chilled a fine fracture. The shrinkage, with most of the steels, goes almost to the bottom of the ingot. This feature is not so marked on the high-carbon steels.

The following conclusions may be drawn regarding the addition of uranium to steel in quantities up to 4 per cent.

(1) Ferro-uranium is a satisfactory agent for addition of uranium to steel. In comparison with uranium metal, the uranium probably stays in the steel better when added as ferro-uranium, because the iron acts as a carrying agent.

(2) A uranium recovery of at least 50 per cent. can be made with all grades of steel up to 4 per cent. uranium.

(3) A uranium recovery of 70 per cent. or better can be made with steel containing less than 2 per cent. uranium.

(4) The recovery is highest when the ferro-uranium employed contains from 25 to 37 per cent. uranium.

(5) When making additions of over 2 per cent. of uranium to steel, a ferro-uranium containing 50 per cent. uranium will probably be the best alloy to use. A 25-per cent. alloy means the addition of too much iron.

(6) A considerable proportion of the carbon and silicon in the ferro-uranium seems to enter the steel.

(7) For a steel containing less than 2 per cent. uranium, the ferro-uranium can be added in the ladle; but a higher percentage of uranium in the steel requires addition in the furnace, or chilling will occur.

(8) A higher uranium recovery is attained when the slag is skimmed, the ferro-uranium added, and the metal poured, than when the ferro-uranium is added without skimming, and the steel immediately poured. However, in the presence of a basic slag, a recovery of at least 50 per cent. of the uranium can be made.

(9) The results do not clearly indicate the proper length of time to leave the steel in the furnace after addition of ferro-uranium. Leaving it in for 1 min. before preparing to pour does not seem to diminish the uranium recovery to a great extent.

(10) The ferro-uranium should be added at about $\frac{1}{2}$ in. size, without much fine material in it; this is especially advisable if added in the presence of slag.

(11) In general, it appears that ferro-uranium should be added after all the other ferro-alloys in use, and the steel should be poured as soon thereafter as possible. There are no data from the ferro-uranium experiments to show the effect of leaving the steel in the furnace for periods greater than 1 min.; but the results with uranium metal indicate that the recovery is highest when the steel is poured shortly after adding the uranium. A fair uranium recovery can be made with almost any type of slag, if the steel is not left in the furnace long enough to permit slagging of uranium.

Addition of Uranium to Steel in Crucible Furnace

Six heats of uranium steel were made at the plant of the Braeburn Steel Co., Braeburn, Pa., with the results shown in Table 34. The alloys had the following compositions: ferrotungsten, 71.75 per cent. tungsten; ferrochrome, 60.75 per cent. chromium; ferrovanadium, 38.52 per cent. vanadium. Ordinary 80-per cent. ferromanganese was used. The high-speed scrap was of varying analysis. The ferro-uraniums were as follows:

	No. 1 per cent.	No. 2 per cent.
Uranium.....	52.87	50.4
Carbon.....	4.74	4.95
Silicon.....	2.33	1.16
Vanadium.....	2.15	3.25
Iron.....	37.2	39.33

TABLE 34.—*Uranium Steel in the Crucible Furnace*

	121	122	123	124	125	126
Charge:						
Wash metal, lb.....	2.0	2.0	2.0	2.0	2.0	2.0
Ferrotungsten, lb.....	4.62	4.62	4.62	4.62	4.62	4.62
Iron, lb.....	50.0	50.0	50.0	50.0	50.0	50.0
Ferrochrome, lb.....	4.31	4.31	4.31	4.31	4.31	4.31
Ferrovandium, lb.....	4.0	4.0	4.0	4.0	4.0	4.0
Ferromanganese, lb.....	1.25	1.25	1.25	1.25	1.25	1.25
High-speed scrap, lb.....	35.0	35.0	35.0	35.0	35.0	35
Ferro-uranium No. 1, lb.....	0.4	1.0	3.0	4.0	5.0	1.6
Ferro-uranium No. 2, lb.....						10.4
Analysis steel:						
Carbon, %.....	0.47	0.64	0.57	0.75	0.78	1.01
Manganese, %.....	nil	tr.	nil.	nil	nil	tr.
Silicon, %.....	0.16	0.32	0.14	0.13	0.16	0.36
Tungsten, %.....	7.50	7.57	8.53	8.37	8.15	6.76
Chromium, %.....	3.46	3.68	3.68	3.69	3.62	3.54
Phosphorus, %.....	0.024	0.032	0.023	0.023	0.020	0.024
Vanadium, %.....	1.38	1.67	1.69	1.87	1.81	2.13
Uranium, %.....	0.09	0.21	0.24	0.88	1.02	3.28
Desired per cent. uranium, 50-per cent. efficiency.....	0.10	0.25	0.75	1.00	1.25	3.00
Ferro-uranium in furnace, min.....	1.0	1.0	1.0	5.0	14.0	14.0

The results indicate that ferro-uranium can be added in the crucible as well as in the electric furnace, with about the same recovery of uranium in the steel.

Manufacture of Ferro-uranium

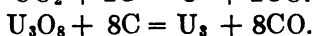
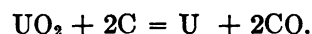
The materials used in the manufacture of ferro-uranium are uranium in the form of sodium uranate or uranium oxide, preferably the latter, fluorspar, petroleum coke, and steel turnings. All of these materials should be as free as possible from impurities, especially silica or silicon. The steel should not contain over 0.3 per cent. carbon, 0.15 per cent. silicon, 0.1 per cent. sulphur, 0.1 per cent. phosphorus. The uranium may be supplied also in the form of slag or residue from previous runs.

The most suitable furnace for the production of ferro-uranium is an electric furnace of the Siemens type, which has the crucible bottom as one electrode and a single suspended electrode. If it is not desired to keep the carbon content of the alloy below 4 per cent. the crucible of the furnace should be made completely of carbon or graphite rammed into place with pitch as a binder. When an effort is being made to keep the carbon as low as possible, the crucible should be lined entirely with ground dead-burned magnesite rammed into place with pitch as a binder, and the bottom electrode connection made by a water-cooled steel contact in the

magnesite. There should be a roof of silica brick over the crucible. The furnace may be of either the stationary or tilting type. Whatever type of electric furnace is used, it must be capable of intense concentration of heat, because of the high reduction temperature of uranium oxide, $1490^{\circ}\text{C}.$, with a carbon reducing agent.

For making ferro-uranium, steel turnings, uranium oxide, petroleum coke, and fluorspar, are all mixed in the proper proportions and charged slowly at a rate dependent on the size of furnace and grade of alloy to be made; the mixture should not be charged so fast as to cool the furnace to any great degree. Regular interval of charging is essential. The metal is poured or tapped into an iron mold. In operation of the furnace, a portion of the charge collects on the wall, protecting the lining.

The reaction involved is that of simple carbon reduction, the reduced uranium alloying with the steel turnings to form ferro-uranium.



Fluorspar is the only slag-forming material that can be used to obtain a reasonable recovery of uranium. It should be used in considerable quantity, and be of a very high grade.

A typical charge for the production of ferro-uranium containing 50 per cent. uranium is given below; also an analysis of the product. The uranium oxide contained 73.33 per cent. uranium, the coke 85 per cent. fixed carbon, the turnings 0.20 per cent. carbon.

Charge	Product
Steel turnings.....15 lb.	Uranium.....50.4 per cent.
Uranium oxide.....40 lb.	Carbon.....4.95 per cent.
Coke.....7 lb.	Silicon.....1.16 per cent.
Fluorspar.....15 lb.	

With a recovery of 75 per cent. of the uranium, 100 lb. of this charge will produce 57 lb. of ferro-uranium, and by resmelting the residue would produce (at 85 per cent. recovery of uranium) about 65 lb. of ferro-uranium.

The uranium recovery in the first smelting, using uranium oxide as source of uranium, is from 60 to 75 per cent. of the uranium charged; in larger-scale work, 85 per cent. might be recovered. On re-treating the residue, the total uranium recovery can be brought to from 85 to 95 per cent. The power consumption is 3 to 5 kw.-hr. per pound of ferro-uranium.

Characteristics of Ferro-uranium and Uranium Metal

Standard commercial ferro-uranium contains 35 to 50 per cent. uranium and 1.5 to 4 per cent. carbon. Ferro-uranium is brittle, has a high density, and when it contains over 20 per cent. uranium has a tend-

ency to be pyrophoric, this tendency increasing with the percentage of uranium. A 3 to 5 per cent. carbon alloy, with less than 15 per cent. uranium, has a dense non-crystalline structure, and is dull gray in color. When the uranium content reaches 18 to 20 per cent., small bright crystals appear; and as the alloy approaches 50 per cent. uranium, these crystals become larger, longer, and more distinct. From 18 per cent. up, the alloy has a brilliant, flaky fracture. At 18 per cent. it is hard to break, but at 50 per cent. uranium it breaks easily. With the commercial 50 per cent. alloy no graphitic carbon is present if the total carbon is under 5 per cent., but if there is over 5 per cent. carbon, this excess carbon is usually graphitic. Any of these alloys has an entirely different appearance if cooled from a white heat in water, this treatment giving it a granular and dirty appearance. If the carbon is less than 1.5 per cent., the alloy has a dense gray appearance and is difficult to break. Under the microscope, the uranium appears to be present as the double carbide of iron and uranium, $\text{Fe}_3\text{C}_2\text{U}_2\text{C}_2$, in a eutectic mixture of iron and carbon.

Uranium metal with over 90 per cent. uranium has a dull black color. It is dense in structure, but powders easily. It is very pyrophoric, and draws a long spark when struck across steel or another piece of uranium metal. Uranium carbide is also pyrophoric, but is more flaky in structure than a mixture of uranium metal and uranium carbide.

SUMMARY

The information contained in this paper has been presented in the hope that it will be of use to others during this period when the country needs all available information, and when there should be no secret process. No attempt is made to cover the manufacture of ferro-alloys beyond the metallurgical side. Furnaces and their operation are not discussed. The greater part of the data have been drawn from commercial operation, and in these cases the conclusions stated are brief. Where the information was gained by experiment, the development of the product through the research is covered in detail.

The metallurgical problems encountered in the manufacture of ferro-alloys have been the production of an alloy with a low percentage of carbon, a high percentage of the alloying element, and a low percentage of impurities, such as phosphorus and sulphur, that might be injurious to the steel. The alloy should have a melting point low enough to be used in a steel bath of ordinary temperature. To obtain this feature it has been necessary, in some cases, to produce an alloy with a high percentage of carbon and a comparatively low percentage of the alloying element, for example, ferrotitanium. The ferro-alloys with a low percentage of carbon are considerably more expensive than the high-carbon alloys, because of the extra refining necessary, which requires a large power consumption, and to a small extent increases the losses. In the case of

some alloys, for example, ferrovanadium and ferrotungsten, the steel manufacturer will not accept a high-carbon alloy, *i.e.*, containing over 1 per cent. carbon, under any conditions, because of the tendency to form carbides in the steel. It is also essential to produce a ferro-alloy of uniform composition, a difficult feature with some alloys. A ferro-alloy which is not fairly uniform is a source of trouble and expense in the manufacture of alloy steel, because it is not possible to regulate closely the composition of the steel.

Carbon control in the electric furnace depends upon two possible characteristics of the alloying metal: first, has it a strong affinity for carbon, or, reduced to fundamental principles, does it form carbides? Second, is the alloying metal easily oxidized? Some metals, such as chromium, manganese, uranium, and vanadium, form carbides even in the presence of a very small amount of carbon at the temperature of the electric furnace, resulting in a high-carbon alloy; while others—for example, silicon and tungsten—show a very slight tendency to form carbides. Some ferro-alloys, when refined to diminish the carbon, show a tendency to lose the alloy metal, because it oxidizes into the slag; examples of this are uranium and chromium. In the case of uranium, it is possible to lose practically all the uranium in the alloy in this manner, even when starting with a 60-per cent. ferro-uranium. On the other hand, tungsten does not oxidize, so that usually, when starting with a 70-per cent. tungsten, 3-per cent. carbon alloy, the refined product will show an increase of tungsten to 75 per cent. and a reduction of carbon to 1 per cent.

There are three general methods of producing low-carbon ferro-alloys: (1) The ore may be smelted with excess carbon to produce a high-carbon alloy with a low slag loss; after breaking up this high-carbon alloy, it may be charged with oxidizing slags to remove the carbon in a refining furnace. (2) The ore may be smelted with about the theoretical amount of carbon to produce a 1-per cent. carbon alloy with a high slag loss, but not followed by any refining process. (3) The ore may be smelted with a metal powder, such as silicon or aluminum, which reduces the metal to a product low in carbon, but high in silicon or aluminum, with a low slag loss; after breaking up this impure alloy, it can be charged with an oxidizing slag to remove the silicon or aluminum in a refining furnace. When using aluminum, it is not usually necessary to adopt a refining operation.

DISCUSSION OF THIS PAPER IS INVITED. It should preferably be presented in person at the Colorado meeting, September, 1918, when an abstract of the paper will be read. If this is impossible, then discussion in writing may be sent to the Editor, American Institute of Mining Engineers, 29 West 39th Street, New York, N. Y., for presentation by the Secretary or other representative of its author. Unless special arrangement is made, the discussion of this paper will close Oct. 1, 1918. Any discussion offered thereafter should preferably be in the form of a new paper.

The Condensation of Zinc from its Vapor

BY CHARLES H. FULTON,* CLEVELAND, OHIO

(Colorado Meeting, September, 1918)

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INTRODUCTION

The study of the condensation of zinc from its vapor was undertaken to shed light on certain problems encountered in large-scale electric zinc-furnace work recently conducted. It is a matter of common knowledge that one of the disadvantages of the arc type, electric zinc furnace, is the production of a large amount of blue powder and proportionately little liquid spelter, for, as stated by Stansfield,¹ "A notable defect in the electric smelting of zinc ores is the difficulty experienced in obtaining the distilled zinc in the liquid state; when zinc ores are smelted electrically, very little liquid metal is commonly obtained, nearly all of the zinc being in the state of powder."

* Professor of Metallurgy, Case School of Applied Science.

¹ A. Stansfield: *The Electric Furnace*, Ed. 2, 325. N. Y., McGraw-Hill Book Co., 1914.

This difficulty was not encountered in the electric furnace used,² the main difficulty being the destruction of the fire-brick lining of the large condenser, in certain parts, and the formation of some oxide and dross coatings on the condensing surfaces. The reason for these difficulties could readily be explained by the infiltration of air whenever the condenser was changed from one retort base to the other, the zinc absorbed in the fire-brick forming oxide and causing rupture by its expanding volume. Two facts, however, tended to disprove this theory for the rupture of the fire-brick lining: first, the large distilling retort, lined with fire-brick, which was shifted from charge to charge on alternate bases at temperatures between 1200° and 1300° C., fully exposed to the air, showed no signs of disintegration whatever; second, marked disintegration in the condenser occurred only in places that were at temperatures ranging between 550° and 450° C. The fire-brick used in the condensers was a Mexico, Mo., brick of excellent grade, but containing numerous "iron spots." An examination of ruined brick and tile showed that these iron spots had been filled with fine sooty carbon, and that rupture was due to the increase of volume due to this deposition. This is a comparatively rare, but well-known phenomenon in the iron blast-furnace, and is clearly described by Frank Firmstone.³

The action is due to the breaking up of carbon monoxide into carbon dioxide and carbon at the temperature at which this reaction is most active (600–450° C.), in the presence of the catalytic agent iron (reduced from the iron oxide by the CO).

This discovery introduced a new problem into the condensation of zinc vapor in large condensers: Is enough carbon dioxide formed by the breaking down of carbon monoxide to interfere seriously with condensation? While practically no blue powder had been formed in the experiments, it was thought that the dross and rock oxide might be due to the carbon dioxide; although the infiltration of air was sufficient to explain their presence, nevertheless the CO₂ might be responsible for it in the absence of oxygen. In the circumstances, analyses of gas taken at the exit of the condenser were considered of no particular value, since, if the CO₂ acted on the metallic zinc vapor to reoxidize it, more CO would be formed, and the fact that there had been a decomposition of CO could not be detected. That the decomposition of CO has an effect on the condensation of zinc has been suggested by Stansfield.⁴

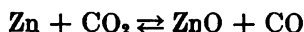
A search of the literature bearing on condensation revealed practically no facts, nearly all of it being speculative. Data on the compo-

² U. S. Patent Office Official Gazette (1917), 234, 1068; 242, 316, 318. 1,213,180; 1,242,337; and 1,242,341.

³ F. Firmstone: An Example of the Alteration of Fire-brick by Furnace Gases. *Trans.* (1903), 34, 427.

⁴ *Op. cit.*, 330.

sition of gases arising from the distillation of zinc ore are practically limited to those given by Ingalls,⁵ which are also stated by R. G. Max Liebig.⁶ No record could be found for the equilibrium conditions of the reaction



except general statements, which are referred to in Part III.

I. DISTILLATION PRODUCTS FROM REDUCTION OF ZINC ORE

Method of Investigation

Experiments were conducted under rigorous conditions to determine the composition of the gas and the condition of the condensed zinc from the distillation of zinc ore. For this purpose porcelain and quartz tubes were used, having been demonstrated to be tight and refractory enough for the temperatures employed. Zinc at high temperatures has great affinity for oxygen, removing traces of oxygen from gases, just as copper does. For this reason it was necessary to insure that oxygen

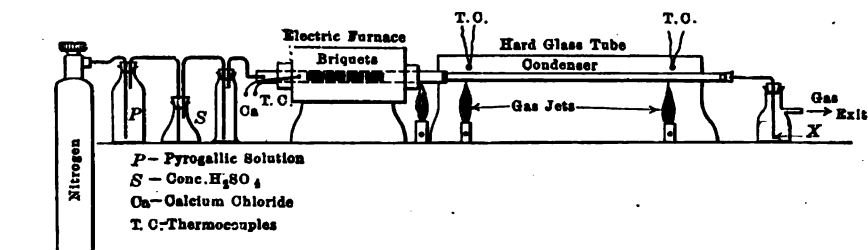


FIG. 1.—APPARATUS FOR INVESTIGATING PRODUCTS FROM DISTILLATION OF ZINC ORE.

was excluded from the system if the relation between the condition of the zinc and the normal gas composition was to be judged. The arrangement of the experimental apparatus is shown in Fig. 1 and 2. The retort part of the tube was heated in a horizontal, granular-resistance, tube furnace similar in design to the vertical tube furnace used by the author in previous work.⁷ The condenser part of the tube was heated, when desired, by a gas-fired combustion furnace. The charge for distillation was in the form of briquets,⁸ made of 100 parts Missouri calamine ore, 80 parts of crushed coke, and 20 parts of hard coal-tar pitch. These briquets were approximately 1 in. (25.4 mm.) in diameter and 1¾ in. (44.4 mm.) long and were quartered longitudinally to fit inside the

⁵ W. R. Ingalls: *The Metallurgy of Zinc and Cadmium*, 204. N. Y., Engineering and Mining Journal, 1903.

⁶ *Zink und Cadmium und ihre Gewinnung aus Erzen und Nebenprodukten*, 380. Leipzig, Spamer, 1913.

⁷ C. H. Fulton: Constitution and Melting-points of a Series of Copper-slugs. *Trans.* (1912), 44, 769.

⁸ U. S. Patent Office Official Gazette (1916), 229, 342. No. 1,193,680.

tube. They had previously been baked at a temperature of about $500^{\circ}\text{C}.$, to drive out the most readily volatile constituents, and contained 18.5 per cent. zinc. The ore contained 39.5 per cent. zinc, 35 per cent. insoluble matter, considerable water, and some carbon dioxide. In composition the briquets were the same as those used in the large electric furnace at East St. Louis, Ill., and do not differ from the charge of the common zinc retort. The gases from the distillation of this material should resemble zinc-retort gas after the charge has been thoroughly dried and heated to about $500^{\circ}\text{C}.$

Oxygen was excluded by the following procedure: the system was thoroughly tested to insure tightness at the temperature used, the quartered briquets were then introduced into the tube, the system closed, and commercial nitrogen (purified by passage through water, pyrogallie solution, conc. sulphuric acid, and calcium chloride) was passed till all

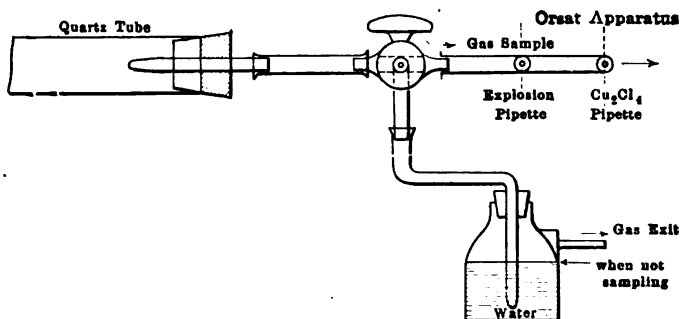
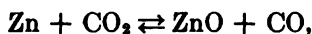


FIG. 2.—DETAIL OF GAS DISCHARGE FROM CONDENSER WHEN USING ORSAT APPARATUS.

air was considered displaced (usually about 5000 c.c.). The furnace was then heated, and, when the gas flow from the distillation was free and it was thought that the nitrogen was displaced, gas samples were taken and analyzed. The sample was taken by inserting the exit tube X, Fig. 1, which was drawn to a small opening, directly into the water-filled rubber connection of the gas burette. Gas analysis was made with the gas burette and Hempel pipettes, great care being taken in regard to temperature conditions, drainage, and connections. It was not considered necessary to employ the exact methods of analysis, using mercury. In some of the experiments an Orsat apparatus was used, directly connected to the exit tube by means of a two-way cock, as shown in Fig. 2.

Approximately 30 gm. of briquet material were used in each experiment, yielding about 3000 c.c. of gas. When the gas flow ceased, the furnace was cooled, nitrogen being passed meanwhile. In later work it was found that when nitrogen, or other gas, was passed through pyrogallie solution, or through both pyrogallie and phosphorus, traces of oxygen remained, which acted on zinc at a temperature between

500° and 700° C. In the above experiments, any traces of oxygen would perhaps be taken up by the carbon of the briquets, but the very slight coatings found on some zinc globules may have been due to this small amount of oxygen; in experiments, described later, conducted in apparatus made entirely of graphite, but not tight against air, some of the zinc was decidedly coated. It is evident from the equilibrium conditions of the reaction



in the presence of carbon, that, when the temperature will permit the formation of dioxide from carbon and oxygen, zinc oxide may form simultaneously.

Table 1 gives the composition of the gases from the distillation of the zinc-ore briquets, under the conditions above described. In all of the experiments using nitrogen as the displacing gas (No. 7 to 16 incl.) the zinc was essentially mirror bright, a slightly coated globule sometimes being found. In the experiments in which hydrogen was the displacing gas (No. 18 and 19), the zinc was coated with the characteristic gray coat, and in some cases zinc oxide crystals were found.

Nitrogen

In the experiments with nitrogen as the displacing gas (No. 7 to 16, incl.), it will be noted that the distillation products contain appreciable percentages of nitrogen. The quantity is too great to be attributed to nitrogen left in the tube, since practically all of this should be displaced by the gas stream from the distillation. To make certain of this point, hydrogen (made from zinc and dilute sulphuric acid and purified as indicated in Table 1) was used as the displacing gas. The distilled gases still contained nitrogen in quantity; hence it must be concluded that nitrogen is a normal gas product of zinc distillation. This is also true of hydrogen, although R. G. Max Liebig,⁹ ascribes both of these gases to diffusion into the retort from the combustion chamber. That diffusion into the retort occurs is unquestionable, as will be shown later; but in the present investigation it seems certain that this possibility was excluded.

In the distillation of coal and the manufacture of coke in byproduct ovens, nitrogen is recognized as a normal constituent of the resultant gas. O. Simmersbach¹⁰ has shown that the gas coming from Kopper's ovens at the end of the coking period, at a temperature of about 1100° C., contains 15 to 17 per cent. nitrogen, and 60 to 70 per cent. hydrogen, the nitrogen being higher at the end of the coking period than at any other

⁹ *Op. cit.* (1913).

¹⁰ O. Simmersbach: Untersuchungen über die Temperaturverhältnisse im Koksofen. *Stahl und Eisen* (June 14, 1914), 34, 954; quoted by F. H. Wagner: *Coal and Coke*, 334. N. Y., McGraw-Hill Book Co., 1916.

TABLE 1.—*Products from Distillation of Zinc Ore*

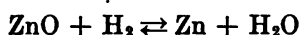
Number	Stage of Distillation	Purification Train for Displacing Gas	Gas Composition						Remarks and Notes
			CO ₂	CO	O ₂	CH ₄	H ₂	N ₂	
7a	Beginning	Conc. H ₂ SO ₄ CaCl ₂	0.65	83.7	Tr.		14.9		39-in. porcelain tube of which 16 in. was heated as a condenser. Zinc mirror bright.
8a	Beginning	Conc. H ₂ SO ₄ CaCl ₂ Pyrogalllic	1.10	78.2	2.2		18.6		39-in. porcelain tube of which 16 in. was heated as a condenser. Zinc mirror bright.
8b	End	Conc. H ₂ SO ₄ CaCl ₂ Pyrogalllic	2.5	79.2	1.3	2.2	6.2	8.4	
11a	Very beginning, 950°C.	Conc. H ₂ SO ₄ CaCl ₂ Pyrogalllic	13.8	40.4	0.0	4.0	27.3	14.5	
11b	Middle, 1150°	Conc. H ₂ SO ₄ CaCl ₂ Pyrogalllic	0.0	78.3	0.0	2.1	13.7	6.1	¾-in. porcelain tube, 21 in. long + 29 in. of ½-in. glass tube not heated. Zinc mostly bright.
11c	End. Temp. very high, 1400°	Conc. H ₂ SO ₄ CaCl ₂ Pyrogalllic	2.2	92.9	0.0	0.7	1.8	2.4	
12a	Beginning, 1000°	Conc. H ₂ SO ₄ CaCl ₂ Pyrogalllic renewed	0.8	70.8	3.5?	1.0	7.0	16.5	39-in. porcelain tube, no part heated as condenser. Zinc bright; few globules coated.
12b	1300°	Conc. H ₂ SO ₄ CaCl ₂ Pyrogalllic renewed	0.95	81.4	0.0	1.3	7.6	8.9	
12c	End, 1500°	Conc. H ₂ SO ₄ CaCl ₂ Pyrogalllic renewed	6.6	59.0	0.0	0.0	9.0	34.5	Gas flow very slow at end.
16a	Beginning, 1050°	Conc. H ₂ SO ₄ CaCl ₂ Fresh pyrogalllic	0.65	61.6	0.0	10.3	10.0	17.3	¾-in. quartz tube 24 in. long. Zinc bright, some with refraction color film.
16b	Middle	Conc. H ₂ SO ₄ CaCl ₂ Fresh pyrogalllic	0.65	79.5	0.0	8.5	6.1	5.3	Gas flow free
18a	Beginning	Conc. H ₂ SO ₄ , H ₂ O, pyrogalllic, CaCl ₂	1.30	77.6	0.0	4.3	15.1	4.4	¾-in. quartz tube 24 in. long. No condenser. Coated sine.
18b	End. Temperature high	Conc. H ₂ SO ₄ , H ₂ O, pyrogalllic, CaCl ₂	0.30	71.7	0.0	4.9	14.3	8.8	
19	Middle	Conc. H ₂ SO ₄ , H ₂ O, pyrogalllic, CaCl ₂	0.0	70.3	0.0	3.3	20.7	5.4	¾-in. quartz tube 24 in. long. No condenser. Coated sine.

NOTES.—The displacing gas was commercial nitrogen in tests No. 7 to 16, incl.; and hydrogen in tests No. 18 and 19. For analysis of the gas, the burette and Hempel pipettes were used in tests No. 7 to 12, incl.; and the direct-connected Orsat apparatus in tests No. 16 to 19, incl.

time. Coke always contains nitrogen, as high as 1.84 per cent. being found in English coke.¹¹ This nitrogen is not expelled completely except at very high temperatures. In experiment 12c, at the very end of the distillation, at a temperature of about 1500° C., the nitrogen was found to be high. This sample was carefully taken when the gas flow had become very slow, and represents the product at the very end of distillation, or even after distillation was complete. The high nitrogen is not to be explained by the supposition that more nitrogen is given off at this time, but rather by the fact that practically no other gases are being evolved, nitrogen being the last gas to be given off. In discussing the presence of nitrogen in the distillation gases, it must be borne in mind that hard coal-tar pitch was used as the binder for the briquets. Since the briquets were baked at a temperature of about 500° C. before distillation, this pitch was converted into a coke, but still contained some heavy hydrocarbons, which break down on further heating. Pitch contains somewhat less nitrogen than coke. It is evident that the remarks on nitrogen also apply to the distillation process when coal is employed as the reducing agent.

Hydrogen and Hydrocarbons

The reduction of zinc oxide by hydrogen according to the reaction



undoubtedly takes place at a markedly lower temperature than the reduction by carbon, and in this experiment reduction by the hydrogen began before the gas flow due to the carbon reaction became pronounced. In the hydrogen reduction, equilibrium conditions demand increasing concentration of hydrogen with increasing temperature; hence as the hydrogen supply decreased, since it was cut off when the furnace was heated, the reaction reversed itself, with the formation of zinc oxide. At the end of the experiment, water was found in the cooler portions of the tube. The action of hydrogen on zinc oxide was investigated by Percy¹² and Deville,¹³ both of whom found that to reduce zinc oxide by hydrogen it is necessary to have a rapidly moving stream of hydrogen; that is, the water produced by the reaction must be removed and not allowed to attain any appreciable concentration, if reoxidation is to be avoided.

The presence of methane and hydrogen in distillation gases is well known. When coal is used as the reducing agent, they represent the decomposition products of hydrocarbons. This is also true when coke and pitch are used, although the amount of hydrocarbons in the reduction

¹¹ H. O. Hofman, *General Metallurgy*, 235, quoting authorities. N. Y., McGraw-Hill Book Co., 1913.

¹² John Percy: *Metallurgy*, 535. London, John Murray, 1861.

¹³ H. Sainte-Claire Deville: Note sur la Réduction de l'oxyde de Zinc et des Alcalis. *Annales de Chimie et de Physique*, Ser. 3 (1855), 43, 479.

material is much smaller. The two gases are most abundant at the beginning of the distillation, and disappear toward the end. In the experiments described, the briquet material occupied a considerable length of the heated tube, and as all of it was not at the same temperature simultaneously; methane and hydrogen were evolved from the cooler ends of the tube even toward the close of the distillation period. This feature may be likened to the condition in the common retort, in which the charge is gradually heated from the outside.

In view of the action of hydrogen in the reduction of zinc oxide, the question arises as to the effect, on the zinc, of the hydrogen normally present in distillation gases. This hydrogen is evolved from the charge in the presence of a large excess of carbon, and if any water does form from the reduction of zinc oxide by hydrogen, it is immediately reduced again to hydrogen, by the carbon, with the formation of CO, CO₂, or both, depending on the temperature. According to a summary by Roscoe and Schorlemmer,¹⁴ at temperatures of about 1000° C., the reaction between carbon and water vapor produces carbon monoxide and hydrogen, with very little carbon dioxide. As the temperature is lowered, the production of carbon dioxide increases, until at 600° C. only carbon dioxide and hydrogen are produced.

The reduction of zinc from ores, by carbon, begins at temperatures ranging from 900° to 980° C., depending on the kind of ore. These figures were obtained by the author some time ago and represent the temperatures at which zinc first becomes visible in the ignited distillation gases from small vertical graphite retorts, heated uniformly to the gas exit in an electric tube furnace. The exact figures were: Mascot, Tenn., ore, 910°; Cañon City, Colo., concentrate, 940°; roasted Joplin blende ore, 940°; Burma, zinc-lead ore, 980°.¹⁵ The reduction of zinc by hydrogen, as previously stated, occurs at a notably lower temperature, although no definite figures are available.

Carbon Monoxide and Dioxide

At the reduction temperature of zinc oxide by carbon, carbon monoxide is the normal reaction product, since, in the presence of an excess of carbon, at this temperature, only very small quantities of carbon dioxide can exist. If, however, zinc oxide is reduced by hydrogen or by methane, evolved from the charge at temperatures below 800° C., the reaction products will consist of water, carbon monoxide, and carbon dioxide in appreciable quantity. It is well known that carbon dioxide in

¹⁴ Sir H. E. Roscoe and C. Schorlemmer: *Treatise on Chemistry*, Ed. of 1905, 1, 793. Macmillan, London and New York.

¹⁵ See also figures by F. O. Doeltz and C. A. Graumann, *Versuche über die Reduktion von Zinkoxyd. Metallurgie* (1907), 4, 290; and those quoted by W. R. Ingalls, *Metallurgy of Zinc and Cadmium*, 2d ed. (1906), 198, and W. McA. Johnson, *Engineering and Mining Journal* (1904), 77, 1045.

certain concentration is highly undesirable in zinc metallurgy, and some definite figures on this subject are given later in this paper. In the author's opinion, the high proportion of carbon dioxide in the distillation gases at the beginning is due to the above described reactions, although some of it comes from the reduction of iron oxides in the ore. Any zinc reduced by hydrogen or methane at temperatures below the carbon reaction will be in contact with distillation gas relatively high in carbon dioxide, and will suffer oxidation, with the consequent production of blue powder. From this standpoint, reduction coal which liberates appreciable quantities of hydrocarbons at relatively low temperatures is undesirable. Hydrocarbons and hydrogen evolved after the carbon reduction temperature has been reached are not harmful.

Carbon dioxide in excess of 1 per cent. is not found in the gases distilled above the carbon reduction temperature; below that temperature as high as 13.8 per cent. was found (experiment 11c, and others not recorded here). At the end of the distillation, the proportion increases, particularly when the temperature is high (above 1400°), the monoxide suffering decomposition into carbon dioxide and carbon.¹⁶ This reaction may have an effect on the zinc when smelting in an arc electric furnace, in which very high local temperatures prevail. Carbon dioxide under 1 per cent. has no effect on zinc vapor either above or within the condensation temperature range, as is shown in Part III of this paper.

Oxygen

Oxygen, except in very small quantities, is not a normal constituent of the distillation gases. A series of experiments was made to obtain information as to the accuracy of the gas apparatus used for estimating small quantities of oxygen in such gases as commercial nitrogen. Oxygen to the proportion of 0.5 per cent. and over was readily determined, but when testing nitrogen, after purification with pyrogallic solution or phosphorus, it was difficult to obtain results which could not be accounted for by slight changes in temperature, absorption by the collecting water, or absorption of other gases by the solutions employed, although heated coppers showed that small amounts of oxygen were still present. It is possible that oxygen in very small quantities was present in the distillation gases, but this was improbable since zinc vapor has a very great affinity for oxygen. The oxygen recorded in samples 8a, 8b, and 12a was probably due to defective sampling.

Condition of Zinc

The zinc condensation was sharply localized in the tube almost immediately beyond the distilling briquets. In experiments 7 and 8,

¹⁶ V. Meyer and C. Langer: *Pyrochemische Untersuchungen. Berichte der Deutschen Chemische Gesellschaft* (1885), 3, 134.

about one-half of the tube was heated uniformly by gas burners to 620° to act as a condenser, but only very small amounts of zinc were found in it, practically all of it being condensed as a mass of globules in the roof of the tube and as a little lake in the bottom beneath these, all within the space of about 1.5 in. (38 mm.). This form of condensation is to be expected from the vapor-tension curve of zinc, which shows that, in a mixture of equal parts of zinc vapor and carbon monoxide, 87 per cent. of the zinc will be condensed within the temperature range of from 865° to 750° C.

In these experiments the heating conditions were such that, immediately beyond the distillation space, the temperature rapidly dropped to between 700° and 800° , so that the zinc, for the most part, condensed here. The tubes were $\frac{7}{16}$ in. (11 mm.) and $\frac{3}{4}$ in. (19 mm.) diameter; and the gas flow being relatively slow, about 30 c.c. per minute, the diffusion of heat into the walls permitted a sharply localized condensation of the zinc. The zinc globules were removed by a wire rod, but the little lakes of zinc adhered so firmly to the tubes that it was necessary to break them to examine the metal. In experiments 7 to 16 inclusive, the zinc was practically all mirror bright; occasionally a globule was found with a slight brown or grayish coat, not discernible to the eye, but plain under the microscope. Adhering to this coated globule were sometimes many small mirror-bright globules. At a certain period of the distillation the gas composition may have been such as to attack certain globules, or the coating may have been due to some substance, as cadmium sulphide or carbon. The coating was not the typical blue-gray coat formed when CO_2 or O_2 is present. Some of the globules had assumed definite crystal structure in solidifying. In that portion of the tube on the side where the displacing gas entered was sometimes found a faint yellow-white film which, when dissolved in dilute HCl, gave the odor of hydrogen sulphide, and, after oxidation with nitric acid, gave a distinct reaction for sulphate. This coating consists probably of a mixture of zinc oxide and cadmium sulphide; the zinc oxide was probably formed by contact of zinc vapor with a small proportion of oxygen remaining in the displacing gas, while the cadmium sulphide probably vaporized as such from the charge. According to Olsen,¹⁷ cadmium sulphide sublimes at 980° C. In experiment 11, a small amount of zinc frost was found; it consisted of bright feathery interlaced crystals of zinc, and evidently had passed directly to the solid state from the vapor. It was not coated. In some of the experiments, on opening the tube the odor of hydrocyanic acid was distinctly noticeable.

Conclusions from Preceding Experiments

When a charge of zinc ore and reducing agent, consisting of coke and the coked residue of hard coal-tar pitch, is submitted to the distillation

¹⁷ Van Nostrand's *Chemical Annual* (1918), 147.

process in a tight system free from oxygen, the zinc is distilled from the charge and then condensed into bright metal with the presence, only occasionally, of a foreign material which might interfere with coalescence; this is probably a sulphide, and carbon, but it occurs in such small amounts as to be technically negligible. Under proper temperature conditions the condensation is sharply localized, and no so-called blue powder is formed.

The gases consist of carbon monoxide, carbon dioxide, methane, hydrogen, and nitrogen. The carbon dioxide is highest at the beginning, but rapidly decreases to below 1 per cent.; toward the end of the distillation, methane and hydrogen disappear, and carbon monoxide increases until it composes by far the greater part of the gas. Nitrogen is persistently present in considerable quantity. Carbon monoxide suffers no appreciable decomposition into carbon dioxide and carbon in passing through the condenser when heated to between 500° and 700° C. This point is again referred to in Part III of this paper.

II. PRELIMINARY INVESTIGATIONS

The experiments recorded above, and the development of the apparatus in which they were carried out, were preceded by considerable preliminary work which revealed the fact that experimental investigation of zinc at high temperature presents difficulties, in that zinc has a very great affinity for oxygen and other oxidizing gases, even in minute quantities, and that if reliable results are to be obtained these must be excluded. An air-tight apparatus is therefore essential. Before this was achieved, some interesting results were obtained with apparatus that was supposed to be tight, but was found not to be so at the temperatures used.

Reduction in Carbon Tube

Since excess of carbon is normal in the usual distillation process, it was natural to try a hard carbon tube as the retort in an electric furnace. A hard, dense carbon tube, $\frac{7}{8}$ in. (22 mm.) diameter with $\frac{1}{8}$ -in. (3-mm.) walls, tight against pressure by blowing, and showing no escape of gas bubbles under water, was used. Other conditions of the experiment, the displacing gas, its purification, and the sampling, were the same as those described in Table 1. A hard glass tube, $\frac{1}{2}$ in. (12.7 mm.) diameter and 36 in. (91.4 cm.) long, heated to 700° to 500° C. along its length, was used as condenser. The zinc obtained from these experiments was found partly in the carbon and partly in the condenser tube, being rather widely disseminated. It was heavily gray-coated, even in the carbon tube, although it had run together quite well. Zinc dust and some oxide were found in the condenser, and zinc dust was carried into the water bottle. The gas had the following composition, in percentage by volume:

Number	CO ₂	CO	O ₂	CH ₄	H ₂	N ₂
1	0.81	58.3	0	5.0	1.3	34.6
2	0.9	51.1	..	48.0		
3	3.0	58.4	..	5.5	2.4	30.6

The system was practically tight, and during the passage of the displacing gas gave no evidence of leaks. At the end of the experiment, the tube was found to be slightly porous when subjected to considerable pressure. The results are therefore explained by the diffusion of air into the tube, as is evident from the high nitrogen contents. During the experiment the interior of the tube was under a pressure of about 4 in. of water. It is interesting to note that zinc was oxidized simultaneously with carbon, by the infiltrated oxygen.

Reduction in Graphite Retort

In order to work with larger quantities of briquet material, a graphite retort was constructed of Acheson graphite, to the design and dimensions shown in Fig. 3. The apparatus included the retort *R*; the condenser

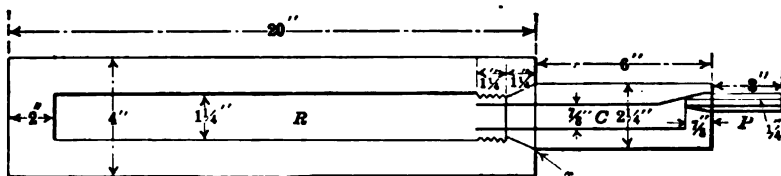


FIG. 3.—GRAPHITE RETORT AND CONDENSER.

C; and the prolong *P*. The condenser was fitted to the retort by a screw-cone joint made tight with stove cement, and the prolong was attached to the condenser by a tight cone joint. The condenser and retort were heavily coated with Johns-Manville high-temperature cement. A glass tube was cemented into the prolong, and the distillation gases were passed through water. The apparatus was heated to the distillation temperature in a large muffle. The gas flow was fast and free during most of the distillation, escaping against a head of 5 in. (12.7 cm.) of water. The sample was taken by inserting the discharge tube directly into the rubber connection of the gas burette.

The charge consisted of 334 gm. of briquets, which, after distillation, weighed 221 gm., a loss of 33.8 per cent. indicating complete distillation, from long experience with this type of material. The amount of zinc recovered was 23 gm., the loss being 38.8 gm.; this was not lost with the gases, for practically none was evident here, but must have been due to absorption and diffusion. The gas composition was as follows, in percentage by volume:

Number	Temp. °C.	CO ₂	O ₂	CO	CH ₄	H ₂	N ₂
1	1200	0.7	0.0	35.6	0.0	0.0	63.7
2	1300	1.4	0.0	72.5		26.1	
3	1350	0.0	0.0	52.6	0.0	0.0	47.5

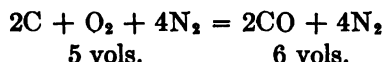
The temperatures were taken by a Pt-Rh thermocouple on the outside wall of the retort at the middle, the retort being uniformly heated throughout its length. The absence of hydrogen and methane is explained by the fact that the gas samples represent the latter part of the distillation and these gases had been expelled.

Experiment with Blue-powder Briquets

Another experiment, in the same apparatus, using briquets made from coke, coal-tar pitch, and high-grade blue powder, gave interesting results. Briquets of this composition should yield very little gas, since there is practically no reduction, and zinc vapor is the only product of the distillation. There was a constant flow of gas from the retort during the distillation, and at a temperature of about 1000° C. its composition was as follows, in percentage by volume:

Number	CO ₂	O ₂	CO	CH ₄	H ₂	N ₂
1	8.6	0.0	28.4	0.0	0.0	62.9
2	3.1	0.0	31.1	0.0	0.0	65.8

This is essentially the composition of producer gas, and is explained by the infiltration of air into the retort, the oxygen uniting with the carbon of the retort. The fact that the gas flows freely from the retort is explained by the increase in volume due to the reaction, as follows:



The zinc obtained in these experiments was partly bright, but mostly gray coated. Considerable blue powder was found in the condenser, although this was heated to the proper temperature by conduction from the retort. The oxidation of the zinc can be explained only by the action of oxygen, since in most cases the carbon dioxide was not high enough to react with zinc, as will be shown later.

Conclusions from Preliminary Experiments

The results obtained with the carbon tube and the graphite apparatus point to some interesting facts in distillation. At first sight, it would appear that such an apparatus must be tight, particularly the retort,

which is made of dense graphite, with walls 1.375 in. thick, but experience proved that diffusion took place freely. Further, in spite of the fact that the retort material was carbon, the zinc was partially oxidized and blue powder was formed, although the temperature conditions for proper condensation to liquid zinc were maintained. This shows that when oxygen comes in contact with zinc vapor, even in the presence of carbon, at a temperature above 1000° , oxidation occurs. From the standpoint of good condensation of zinc, a tight distillation system is essential; not only must there be no openings into the system, but the material from which it is constructed must be proof against the powerful diffusion forces at work. It seems probable that much of the difficulty experienced in recovering a high percentage of liquid spelter, in the common retort process, is due to porous retorts and condensers. That there is considerable gas pressure outward from the retorts and condensers means but little when diffusion forces are at work.

These remarks apply with still greater force to the electric zinc furnace of the arc type, and it would be remarkable if such furnaces as have been used did not yield large percentages of blue powder. This subject is again referred to later in this paper.

III. EQUILIBRIUM OF REACTION $\text{Zn} + \text{CO}_2 \rightleftharpoons \text{ZnO} + \text{CO}$ IN TEMPERATURE RANGE OF CONDENSATION

That zinc is oxidized by carbon dioxide is well known, but the author was unable to find definite data in the literature. The work described in the first part of this paper proves that the "normal" gases arising from distillation, and present during the condensation, containing up to approximately 1 per cent. or slightly more of CO_2 , have no deleterious effect on condensation. Under certain conditions, more CO_2 may be present, as in the case of early reduction by hydrogen or hydrocarbons, or by the decomposition of carbon monoxide.

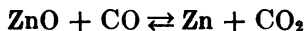
Zinc oxide is reduced to zinc by carbon monoxide at 600°C .¹⁸ and zinc is oxidized by CO_2 at red heat, with the formation of CO , this gas constituting over 90 per cent. of the gas issuing from the experimental tube. One of the methods of making CO gas, given in laboratory manuals, is to pass CO_2 over heated zinc.

A. Lencauchez¹⁹ states that at white heat ZnO is reduced to Zn by CO , but that as the vapor and gases of the reaction pass to the cooler portions of the tube, the CO_2 reoxidizes the zinc. He also states that blast-furnace gas containing 24 per cent. CO and 12 per cent. CO_2 readily reduces ZnO at white heat, but as the temperature falls to cherry red

¹⁸ Doeltz and Graumann: *Ibid.*

¹⁹ A. Lencauchez: *Métallurgie du Zinc de la Condensation des Vapeurs de Zinc dans les appareils soufflés. Mémoires de la Société des Ingénieurs civils (1877)*, 568, 580.

(which he states is equivalent to 1200° C.) the CO₂ reoxidizes the zinc vapor. These statements indicate that in the reaction



equilibrium requires an increasing concentration of CO₂ with increasing temperature, and a decreasing concentration of CO, the reducing agent, with increasing temperature. This is the opposite condition to that prevailing in the ZnO-hydrogen reaction, and most other reactions involving the reduction of metallic oxides by CO. In the experiments described below there was nothing to indicate that the nature of the ZnO-CO reaction differed in this respect from the ZnO-hydrogen reaction.

Method of Investigation

A piece of pure²⁰ bright zinc, in a porcelain boat, was placed in a ½-in. (12.7-mm.) hard glass tube 36 in. (91.4 cm.) long, heated in a gas combustion furnace having a mica sheet immediately over that part of the tube containing the zinc, so that the condition of the metal could be readily observed during the experiment. Purified mixtures of CO and CO₂ were passed, and the effect on the zinc was noted. The temperature was measured by a Pt-PtRh thermocouple, having its junction placed directly over the center of the zinc and touching the outside of the glass tube. The temperature could be held steadily at any point in a range from 500° to 700° C. The vapor tension of zinc is such that, within the temperature range adopted, zinc vapor in considerable quantity formed in the tube and was in contact with the stream of gas. This zinc vapor condensed in the cooler portions of the tube, and in part on the cooler sides of the porcelain boat. The deposited metal could afterward be examined under the microscope, which made it easy to distinguish sharply between bright metal, oxide, and coated metal. When oxide formed, it would partially deposit on the upper side of the tube immediately above the head of the porcelain boat, and also further along; but when the composition of the gas was such that no oxide formed, this head deposit would be absent, and bright zinc metal would condense in globules, and as a mirror, above the end of the boat and further back in the cooler portion of the tube.

Fig. 4 shows the arrangement of the apparatus as used in the final successful experiments, after considerable work had been done to ascertain the proper conditions for success. At first, carbon monoxide, made from potassium ferrocyanide and sulphuric acid, was passed directly into the gas storage S, which also received the carbon dioxide made from pure marble and dilute HCl. The gas storage bottle was graduated and any desired mixture could be made. The mixed gases were purified by passage through water, phosphorus, conc. sulphuric acid, and anhydrous calcium chloride. Under these conditions, carbon monoxide free from

²⁰ The analysis was: Pb, 0.04; Fe, 0.025; Cd, 0; As, tr.

carbon dioxide formed coatings on the zinc, and the difficulty was ascribed to small quantities of SO_2 in the gas, derived from the ferrocyanide and sulphuric acid reaction. The presence of sulphur was proved in the coatings, which consisted of zinc sulphide and oxide. The purification system was then modified by the addition of concentrated potassium hydrate solution between the CO generator and the gas storage, and the insertion of $\text{N}/20$ iodine solution between the water wash and the phosphorus bottle; also when pure CO was being used, by the further addition of KOH solution between the phosphorus and the conc. H_2SO_4 bottle.

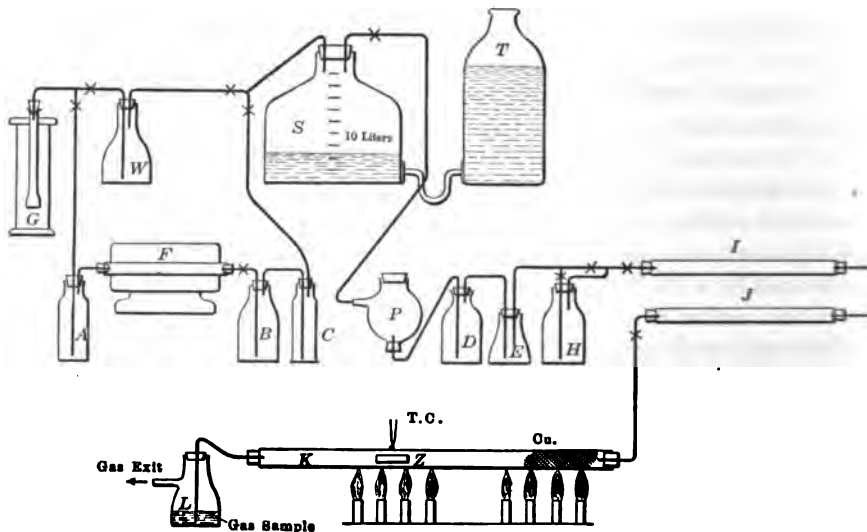


FIG. 4.—ARRANGEMENT OF APPARATUS FOR EQUILIBRIUM TEST.

- | | | |
|-----------------------------------|------------------------------------|-----------------------------------|
| A. Na_2CO_3 water | H. Conc. KOH with by-pass | T. Pressure bottle |
| B. Pyrogallie solution | I. Anhydrous CaCl_2 | W. Na_2CO_3 water |
| C. Conc. KOH solution | J. P_2O_5 | Z. Zinc in boat |
| D. Na_2CO_3 water | K. Combustion tube | Cu. Copper gauze |
| E. Water | L. Wash bottle | T.C. Thermocouple |
| F. Electric furnace, charcoal | P. Phosphorous | X. Stop- and pinch-cocks |
| G. CO_2 generator | S. Gas storage | |

The difficulty still persisted, and coatings containing sulphur were formed. Further investigation showed that very minute quantities of sulphuric anhydride mist, originating in the CO generator, passed unaltered through the long purification train and attacked the zinc. The ferrocyanide and sulphuric acid method of making carbon monoxide was therefore abandoned, and the method of passing CO_2 over charcoal heated in an electric tube furnace was adopted. The CO_2 , made from marble and dilute hydrochloric acid, was passed through Na_2CO_3 solution, over the heated charcoal, through pyrogallie solution, and concentrated KOH solution, to the storage bottle. From the storage it passed through phosphorus, iodine solution, water, conc. KOH , (in case pure CO was being used), then through anhydrous calcium chloride, and phosphorus

pentoxide. The white zinc oxide deposit still formed, but no sulphur was now present. The formation of oxide was due to minute quantities of oxygen which were not removed by the pyrogallic solution and phosphorus, although the phosphorus was active, no inhibiting catalyzers being present, and the gas stream did not exceed 30 to 40 c.c. per minute.

The final purification train then adopted was as last described, with the addition of copper gauze and shredded copper placed in the glass tube, near the end where the gas stream entered, and the replacement of the iodine solution by Na_2CO_3 solution. This train removed the troublesome foreign constituents from the gas stream, and further experiments gave consistent results.

The difficulties encountered are briefly outlined above for the purpose of showing how readily errors can be made in the investigation of a metal like zinc, which has such strong chemical affinity at the temperature of condensation.

For determining the composition of the gas mixture, the following method was used. The pure gas, or the mixture, would be accumulated in the storage bottle, which was then thoroughly shaken to insure a uniform gas. The copper was then heated to redness, and the gas was passed through the train at the rate of 30 to 40 c.c. per minute, until from 2500 to 3000 c.c. had been used. The sample was then taken in the manner described in Part I, an accurate glass stopcock burette, graduated to 0.1 c.c., being used in connection with Hempel gas pipettes for analysis. The analysis thus obtained represented the composition of the gas in contact with the zinc.²¹ The gas burners under the zinc were then lighted and the experiment carried through to the end. Aside from CO and CO_2 , the gas contained usually between 5 and 8 per cent. of nitrogen²² and fractions of 1 per cent. of H_2 . The source of the nitrogen is the charcoal, small amounts probably being due to the marble. The hydrogen comes from decomposed water vapor. The presence of these gases is not detrimental, since they represent normal constituents of distillation gases, which do not affect condensation.

Conclusions from Equilibrium Investigation

Table 2 contains the experimental data and Fig. 5 is the equilibrium curve drawn from these data. The gas composition is recalculated on the basis of a mixture consisting of CO and CO_2 only, omitting the nitrogen and hydrogen content. The results may be summed up in the statement that, within the condensation range between 500° and 700° C., distillation gases must not contain more than 2.5 per cent. CO_2 if oxidation of the zinc is to be avoided entirely; when present between 2.5 and 5 per cent.

²¹ Metallic copper at red heat is without action on carbon dioxide or carbon monoxide. F. V. Bacho: *Monatsh* (1916), 37, 119.

²² Probably all nitrogen, though other gases related to N_2 may be present.

TABLE 2.—*The Action of CO₂ on Zinc*

Number	Gas Composition before Passage		Gas Composition after Passage		Temperature °C.	Action on Zinc	Remarks
	CO ₂	CO	CO ₂	CO			
26	0.8	99.2	.....	.....	653	None	Zinc all bright. Slight carbon deposit on zinc in boat and on porcelain boat.
27	13.1	86.9	.....	.....	635	Decided action	ZnO coat on tube. Typical blue powder formed. Zinc coated gray. ZnO crystals present.
28	2.3	97.7	1.7*	98.3	647	None	Zinc all bright. Carbon deposit evident, but slight.
29	5.6	94.4	5.6	94.4	533	Action present	Slight amount of oxide at head of boat. Zinc beyond bright.
29a	5.6	94.4	.....	.....	711	Decided action	ZnO formed at head and also further on; appears yellow when hot. Zinc in boat gray coated. ZnO crystals.
30	7.4	92.6	.....	.....	535	Distinct action	ZnO at head of boat. Carbon deposition noticeable. Carbon spots on zinc in boat. Color films on zinc.
31	4.5† 4.0	95.4† 96.0	2.1†	97.9†	534	Action slight	Slight amount of ZnO at head. Color films on zinc in boat. Some carbon deposit.
32	2.0† 2.2	98.0† 97.8	.....	.....	574	No action	Zinc all bright. Mirror. Carbon deposit slight.
32a	2.0	98.0	.....	.....	705	No action	Zinc bright.

* Not certain; probably low.

† The upper figure is the composition of the gas after passing the heated tube containing copper; the lower figure is the composition before entering the tube. The difference may be considered as due to the decomposition of CO according to the reaction $2\text{CO} \rightleftharpoons \text{CO}_2 + \text{C}$, which is evidently not pronounced.

‡ Taken after standing in contact for some time, with no gas flow.

the action of CO₂ is comparatively slight; when more than 5 per cent. is present, oxidation is pronounced, and blue powder begins to form.

That decomposition of CO occurs in the condenser tube is evident from the slight carbon deposit formed, but it is small and its detection by analysis of the gas going in and coming out is uncertain, as the slight differences in composition are not readily determined. This confirms the data obtained from the experiments on composition of distillation gases, previously described, based on experiments 7 and 8. It is therefore concluded that in a condenser system in which there is a movement of gas not under normal speed (*i.e.*, one at which condensation of zinc vapor can readily take place) the decomposition of CO is not sufficient to interfere with condensation.

The reaction $2\text{CO} \rightleftharpoons \text{CO}_2 + \text{C}$ has been thoroughly investigated,²³ and it need only be stated here that it proceeds from left to right much more rapidly at 500° than at 700°, and that the catalytic agents iron or nickel have a great influence on the speed of the reaction. It is advisable, therefore, in the design of a condenser, not to use structural material containing iron, or iron itself, in its interior; neither should the gas velocity be too slow, nor should the condenser be held at too low a temperature (450° to 500° C.). The last difficulty may be overcome by the use of a primary and a secondary condenser, the first being larger and held at the higher temperature range, while the second is smaller and held at the lower temperature range.

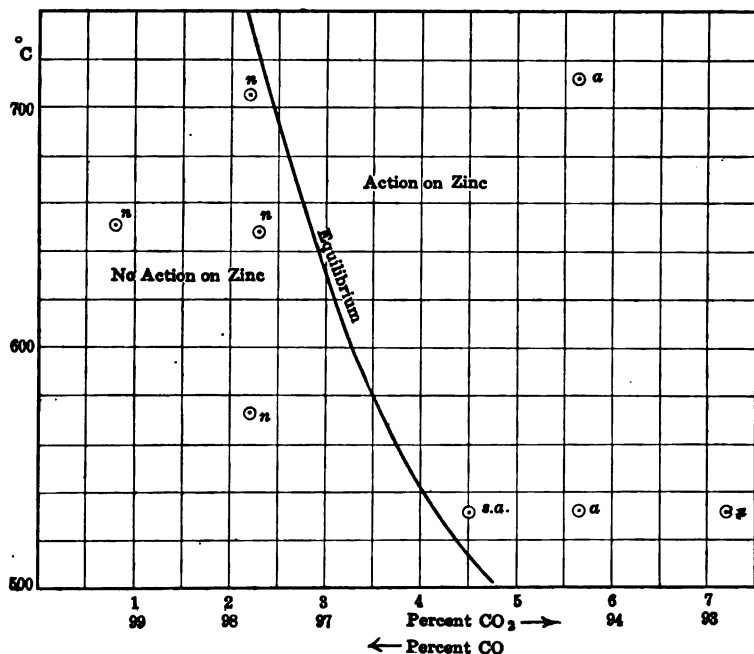


FIG. 5.—EQUILIBRIUM CURVE OF THE REACTION: $\text{Zn} + \text{CO}_2 \rightleftharpoons \text{ZnO} + \text{CO}$.

Conditions of the Zinc in Equilibrium Experiments

In the preceding experiment, a relatively small amount of zinc vapor was contained in a large volume of gases. When the CO₂ was below the quantity necessary for attack on the zinc, the metal condensed beyond the heated zone of the tube in minute drops and globules firmly adherent to the glass, and all were mirror bright. Further along, a metal mirror would appear. In most of the condensing region the temperature was

²³ R. Schenck and W. Heller: *Berichte der Deutschen Chemische Gesellschaft* (1905), 38, 2139; R. Schenck and F. Zimmermann: *Ibid* (1908), 36, 1232.

below the melting point of zinc. The general appearance was very similar to that of water vapor condensing on a pane of glass. There was no loosely adherent powder, but toward the very end of the tube there were minute shining crystals of zinc. The zinc in the boat was partly bright and in part covered with a brown film and dark brown spots which were taken to be carbon.

When CO_2 was present in sufficient amount to attack the zinc readily, loosely adherent gray coatings and deposits formed above the boat, and further along, typical blue powder, accompanied by bright metal globules and white oxide films.

In the absence of interfering substances, the condensation of zinc vapor into liquid metal drops, and the coalescence of these drops into a bath of metal, present no particular difficulties. The coalescence of the zinc drops is governed by surface tension and related forces, and if these could be diminished, condensing surfaces might be made more efficient. The subject presents an interesting field for investigation.

IV. REQUISITES FOR SUCCESSFUL CONDENSATION

The object of the experimental work detailed in this paper was to determine certain fundamental facts in the distillation and condensation of zinc, in order to find an answer to the question—Are any products formed during the distillation of zinc ore and the subsequent condensation of the zinc vapor which interfere with the condensation to liquid metal; if so, what are they, and in what proportion are they harmful?

The results of the investigation show that under proper conditions there is nothing to interfere with the condensation of the zinc to liquid metal, but that the latitude within which operations may be carried on is not wide. One requisite is that the distillation and condensation systems must be tight and impervious to air. This, of course, has been well known, but the fundamental reason for it has not been recognized. Many of the electric zinc furnaces that have been experimented with, or proposed, suffer from this vital defect, the arc furnace being particularly defective on this point. If operated continuously, by feeding ore and reduction carbon, and discharging slag, there will be regions in the furnace, in the cooler portions above the smelting arcs, where carbon dioxide will form in considerable proportion, according to the principles discussed in this paper. For an electric zinc smelting furnace to be successful, it must be able to obtain a uniform temperature rapidly throughout its whole distillation chamber; certainly no part of the chamber or its contents should be below 950° to 1000° C. From the standpoint of the condensation of vapor, it is not possible to distil at 1200° C. in one part of the chamber, while the products of distillation come in contact with ore charge at below 1000° C. in another part, and at the same time condense a large proportion of the vapor to liquid spelter.

DISCUSSION OF THIS PAPER IS INVITED. It should preferably be presented in person at the Milwaukee meeting, October, 1918, when an abstract of the paper will be read. If this is impossible, then discussion in writing may be sent to the Editor, American Institute of Mining Engineers, 29 West 39th Street, New York, N. Y., for presentation by the Secretary or other representative of its author. Unless special arrangement is made, the discussion of this paper will close Nov. 1, 1918. Any discussion offered thereafter should preferably be in the form of a new paper.

Notes on Babbitt and Babbitted Bearings

BY JESSE L. JONES,* A. B., PITTSBURGH, PA.

(Milwaukee Meeting, October, 1918)

(Contributed through the courtesy of the former American Institute of Metals.)

SUMMARY

1. BRINELL tests at progressively increasing temperatures are given for a representative lead-base and a representative tin-base babbitt, showing that the former has superior resistance to deformation at the working temperatures of bearings.

2. Small squares of bearing bronze, tinned and then babbitted with a representative lead-base babbitt and a representative tin-base babbitt were subjected to compressive loading. The lead-base babbitt showed less average compression than the tin-base babbitt. Compression did not materially increase the Brinell hardness of the babbitts.

3. A process and a tool are described for giving smoother and more accurate surfaces to bearings than has heretofore been possible.

The following experiments have recently been carried out in the chemical laboratory of the Westinghouse Electric and Manufacturing Co., Pittsburgh, Pa. While the work is incomplete, it is described at the present time because data on the comparative merits of lead-base and tin-base babbitts are of interest in connection with the present shortage of tin.

BRINELL HARDNESS OF BABBITT AT INCREASING TEMPERATURES

Bearings fail because of wiping, or deformation. Hence tenacity is desirable in a bearing metal, especially tenacity at high temperatures. The Brinell test is commonly regarded as a measure of tenacity. In fact, it has recently been proposed to substitute for Brinell hardness number the expression "tenacity number."¹ It seemed, therefore, that the Brinell test was especially adapted for the tests described.

Disks, 4 in. (101 mm.) in diameter and 1.5 in. (38 mm.) thick, were made of the babbitts to be studied, designated A, B, C. They were poured into metal molds, pyrometer leads being soldered in the center of each disk. The composition of the babbitts was as follows:

* Metallurgist, Westinghouse Electric & Manufacturing Co.

¹ J. W. Craggs: Notes on Testing Hardness of Metals. *Journal of the Society of Chemical Industry* (1918), 37, No. 3, 43T.

	A	B	C
Antimony.....	8	8½	14
Copper.....	2	8½	Nil
Lead.....	Nil	Nil	78
Tin.....	90	83½	8

The disks were heated by an electric hot plate, the heating being controlled by suitable rheostats. The thermocouple leads were connected with a Leeds & Northrup potentiometer, for measuring the temperatures. The disks were well insulated to prevent radiation losses, and after the desired temperature was reached it was held for several minutes to guard against variations.

The Brinell hardness tests were made on the bottom surfaces of the disks, a light machining cut being taken from each sample in order to

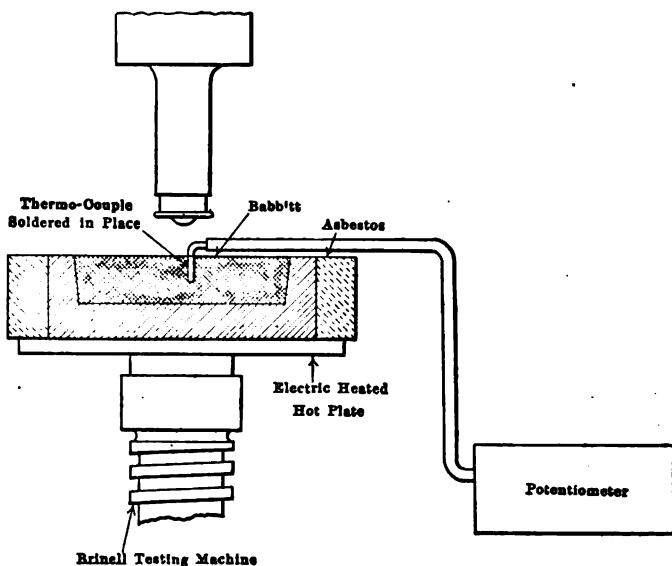


FIG. 1.—ARRANGEMENT OF APPARATUS FOR TESTING HARDNESS OF BABBITT AT VARYING TEMPERATURES.

secure a perfectly plane and smooth surface. Fig. 1 gives a sketch of the apparatus used for the test. The Brinell hardness numbers were plotted, giving the curves shown in Fig. 2.

At 35° C., the hardness of the A and C babbitts is identical, but above this temperature the lead-base babbitt has the greater hardness.

The curves for babbitts B and C are almost parallel, and not far apart: it is seen that the C curve is slowly approaching the B curve. Complete results from the various testing departments of the Westinghouse company, covering a number of years and a great variety of motors, confirm the superiority of the lead-base babbitt. The number of wiped bearings

that had to be rebabbitted was about 100 per month with the *A* babbitt, but not more than six per month when the *C* babbitt was used.

These practical results have led to the adoption of the *C* babbitt for all classes of machines, and the complete elimination of *A* or tin-base babbitt. Both experimentally and practically the lead-base babbitt has shown greater resistance to wiping or deformation at working temperatures than the tin-base babbitt.

The hard, genuine babbitt *B*, the test of which is shown in Fig. 2, while not regularly used, has been found very serviceable in the Kings-

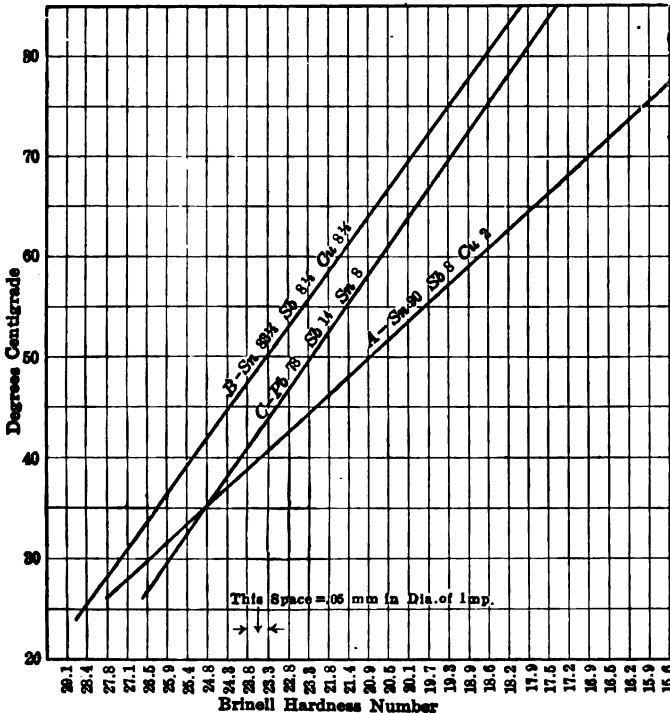


FIG. 2.—HARDNESS OF THREE BABBITTS AT VARYING TEMPERATURES.

bury step bearing and other situations where the bearing pressures have been rather high. While the Brinell hardness shown in Fig. 2 for the *A* and *C* babbits is not far from the average hardness found for these alloys when using the standard hardness test piece, the hardness observed for the *B* babbitt is much below normal; it should be about 38. The reason for the low Brinell hardness of this babbitt is probably the fact that it is difficult to prevent the large amount of copper in this alloy from segregating, even when it is kept very hot and stirred continuously. The *B* formula is almost the same as the genuine babbitt of the Society of Auto-

mobile Engineers. It is also similar to the alloy known as Fahrig metal, that is much used for lining aeroplane bearings abroad.

As it is the common belief among mechanical engineers that the addition of even a small amount of lead to a genuine babbitt renders it inferior, similar tests to those described above were run on the A babbitt, to which 1, 3 and 5 per cent. of lead had been added. The addition of 1 per cent. of lead to the A babbitt made a decided improvement in its resistance to deformation at increasing temperatures. Additions of more than 1 per cent. of lead did not increase the hardness in the same ratio.

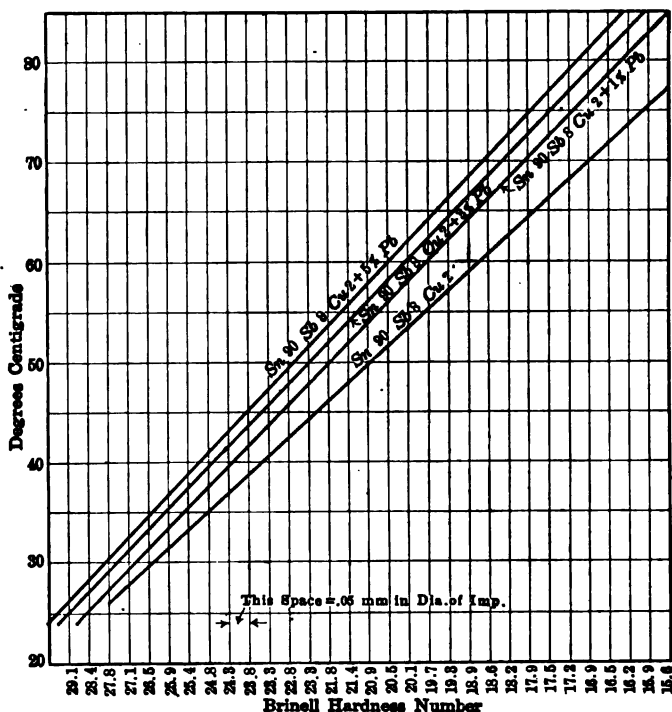


FIG. 3.—EFFECT OF LEAD ON HARDNESS OF A BABBITT.

The results of these tests are shown in Fig. 3, and are in harmony with the observations frequently made by users of babbitt, that when a small amount of lead has been added accidentally to a tin-base babbitt, its hardness and anti-frictional qualities have been much improved.

EFFECT OF COMPRESSION ON THE BRINELL HARDNESS OF BABBITTS

After a babbitted bearing has been bored out nearly to size, it may next be scraped until an accurate fit is obtained. This is a tedious operation and demands a skilled mechanic; hence reaming or broaching are often used instead of this method. A reamer can be passed through a

number of bearings so that they will all be lined up in one operation. Reaming, at its best, however, is a rather violent operation, especially after the reamer becomes dull. Broaches are pushed through the bearing by a hydraulic press until the required dimensions are reached. In the case of large bearings, peening or compressing the babbitt by hammering is often specified. The last two operations, in particular, are supposed to compress the babbitt in a bearing and harden it so that it will give better service. The following experiment was made to ascertain the effect of compression of babbitt on its Brinell hardness.

Two phosphor-bronze plates (Cu, 80; Sn, 10; Pb, 10; P, 0.5 per cent.), 2 in. (50 mm.) square by $\frac{1}{2}$ in. (12.7 mm.) thick, were machined all over;

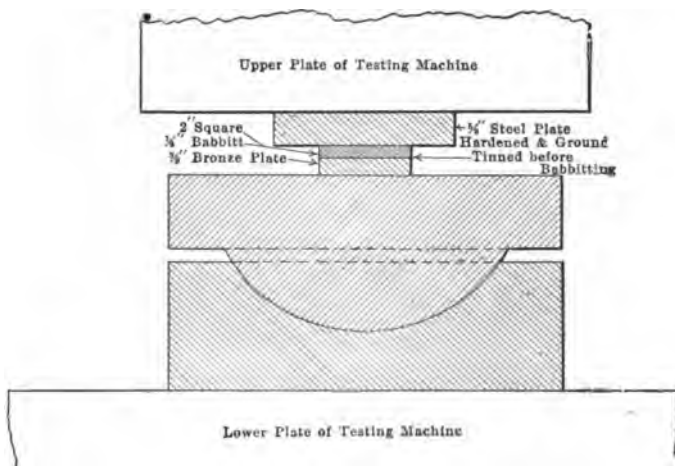


FIG. 4.—APPARATUS FOR COMPRESSIVE TESTS OF BABBITT.

one face was then tinned and babbitted with $\frac{1}{4}$ in. (6.3 mm.) of babbitt, *B* babbitt being used on one sample and *C* babbitt on the other. The babbitt was machined to $\frac{1}{4}$ in. and the samples subjected to a compressive test in the apparatus shown in Fig. 4, so designed that the load would be distributed as uniformly as possible. The successive loads and the corresponding Brinell hardness tests are given in Table 1.

TABLE 1.—*Compression and Hardness of Babbitts*

Load, lb. per sq. in.	<i>B</i> Babbitt		<i>C</i> Babbitt	
	Compression, in.	Brinell	Compression, in.	Brinell
8,500	0.0020	33.6	0.0015	23.8
10,000	0.0020	33.6	0.0020	23.8
11,000	0.0055	33.6	0.0030	24.8
12,000	0.0085	33.6	0.0032	24.8
13,000	0.0140	33.6	0.0102	24.8

The lead-base babbitt withstood compression better than the tin-base babbitt. When the load was increased to 30,000 lb. per square inch, however, the latter presented the better appearance, as the babbitt had flowed uniformly in all directions over the edge of the bronze square, while the lead-base babbitt compressed more on one side than on the other, and the sample tilted in spite of the rocker device. At a load of 30,000 lb. per square inch, the bronze also flowed appreciably.

These tests show that broaching, peening, etc., do not appreciably increase the hardness of babbitt, and that hardness must be obtained by quick cooling of the lining by water-cooled mandrels, etc.

Microscopic examination of a lead-base babbitt discloses a matrix or groundmass of several eutectics in which are embedded hard cubical

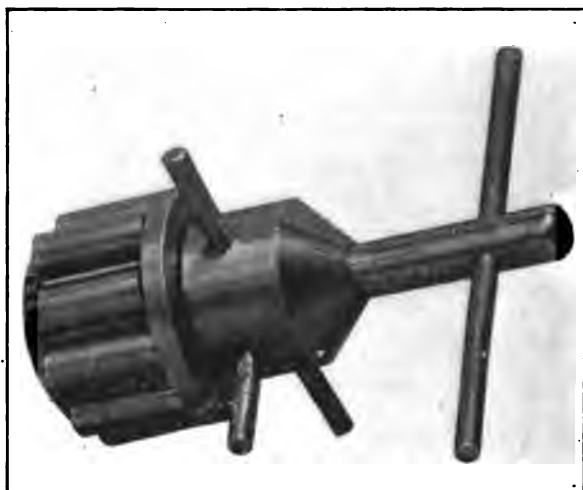


FIG. 5.—THE MILLS MICROMETER ROLLER.

crystals of tin antimonide. These crystals, being relatively low in specific gravity, tend to be more numerous in the upper portion of a babbitt lining. This lack of uniformity is guarded against by pouring a thin lining and chilling quickly. The secret of obtaining good bearings consists in keeping this matrix tough and hard. The same remark applies to the tin-base babbitts, although in these there is less tendency for the tin antimonide crystals to rise to the surface, owing to the lower specific gravity of these babbitts.

ROLLING OF BABBITTED LININGS BY THE MILLS MICROMETER ROLLER

As the above test of Brinell hardness of babbitt after compression showed practically no change in hardness, it was concluded that the various methods of finishing babbitted bearings, such as peening, broaching, and reaming, did not improve the hardness of the babbitt. As,

after these operations and the final scraping, it is still necessary to make a test run of bearings until the shaft is seated, it seemed possible to introduce improvement in the usual method of procedure. The so-called glass-like surface of old bearings is considered very desirable. Even if the babbitt is no harder than when cast, all inequalities of the surface have been smoothed out and friction has been reduced to a minimum. It occurred to the writer that, by a rolling or burnishing operation, this desirable finish could be given to babbitt linings so that a machine could be operated at full speed as soon as finished, without any trial run.

A tool, Fig. 5, designed by I. Mills, seems capable of doing this work satisfactorily. It was made for securing a better seat for the ball-bearing races of a small aeroplane wireless generator. A variation of 0.0007 in. (0.018 mm.) was found in the bearings, which could not be corrected by reaming or machining. With this tool, the seats in the aluminum alloy end brackets can be rolled to suit the individual variations of the ball bearings. A girl does the rolling, and the bearings can then be inserted or removed with the fingers. If the work is done by reaming, bearings may fit tightly at first, and after having been taken out may be quite loose, because burs, etc., have been removed.

While the Mills micrometer roller has been made only in a very small size as yet, it can be made in larger sizes and would then be capable of exerting much greater pressures. The present instrument is made for a diameter of $1\frac{3}{4}$ in. (44.5 mm.) and has a range of 5 mils plus and minus. It consists of 10 rolls which can be expanded by a micrometer screw through the medium of two tapered cylinders which give a parallel outward movement to the rolls. The essential feature of the instrument is that the rolls are not equally spaced, as this would cause them to flute the rolled surface.

A trial of this method of rolling babbitted linings is being made on two sets of connecting-rod crank-shaft bearings of the Liberty engine, one set being filled with the lead-base babbitt *C*, and the other with the tin-base babbitt *B*. A description of the difficult conditions that are encountered in the bearings of the Liberty engine, due to its great power, are given in a very interesting paper, "The Metallurgist and the Aircraft Program" by Lieut. H. F. Wood, U. S. Army, Signal Corps.²

² *Proceedings of the Steel Treating Research Society* (April, 1918), 1, No. 9, 15.

INDUSTRIAL SECTION

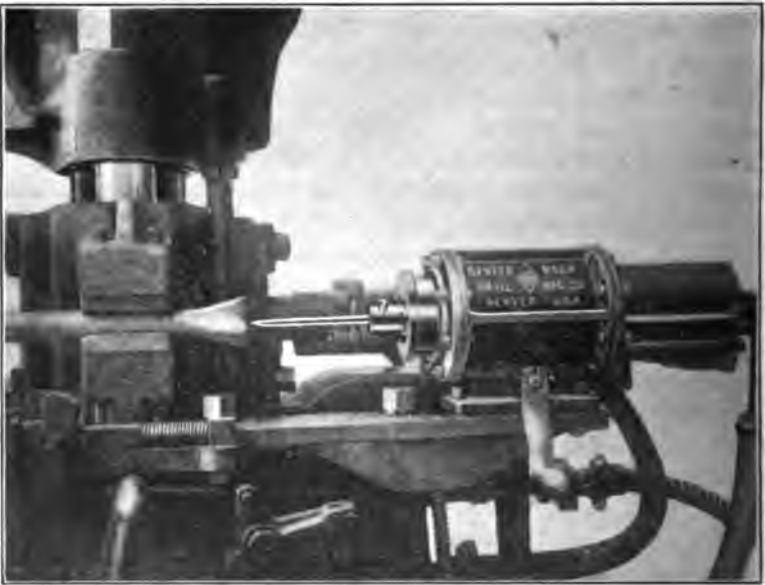
This department is devoted to material concerning the products or operations of manufacturers, which, in the estimation of the Editor, is of news value to the mining and metallurgical field, but does not come within the scope of the main editorial section of the Bulletin.

Manufacturers are invited to submit to the Editor items descriptive of new equipment or processes, large or significant installations, and similar material of news character. If found available, items thus furnished will be published in this section without charge, subject to such editorial revision and condensation as may be necessary.

In cases where illustrations are required, cuts of the proper size should accompany the text matter.

THE MODEL 10 "WAUGH" DRILL-STEEL PUNCHER

A handy little device for opening up the water hole in hollow steel has just been placed on the market by the Denver Rock Drill Manufacturing Co., Denver, Colo. It consists of a punch and hammer set in an air-feed cylinder, which drives the punch into the steel and withdraws it in combination with the hammer



action. It is designed for use with the Model 8 sharpener to be mounted on the pedestal back of the clamping vise, but it may be mounted separately or even adapted to other machines. The operation is extremely simple, and a slight alteration of the control handle will either drive it forward or withdraw it. This device will open the water hole in a bit or shank in one-tenth the time required to perform such operation by hand.



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